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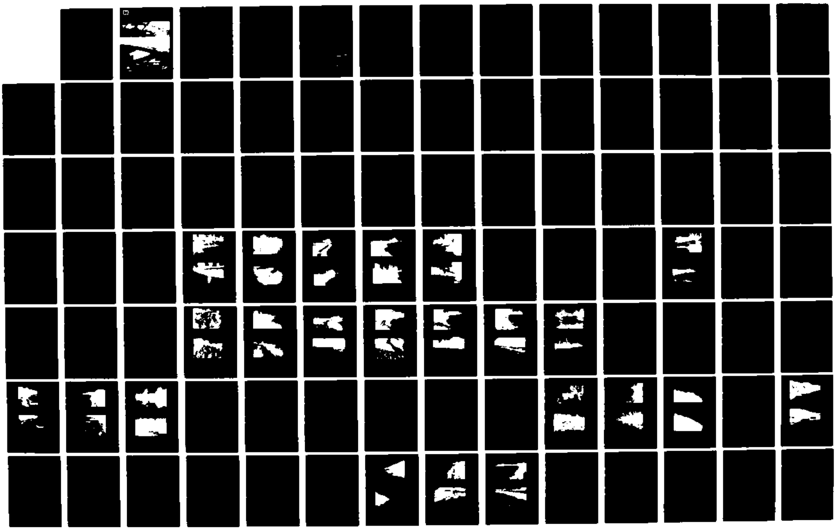

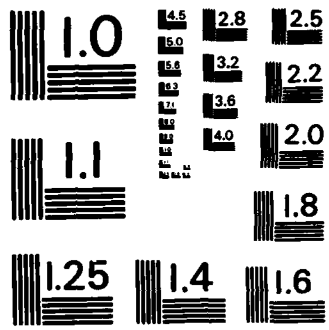

MICROCOPY RESOLUTION TEST CHART
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US Army Corps of Engineers

December 1981

THE STREAMBANK EROSION CONTROL EVALUATION AND DEMONSTRATION ACT OF 1974 SECTION 32, PUBLIC LAW 93-251

Appendix E - Missouri River Demonstration Projects

Volume 2 of 2

Rock Toe With Tie-Backs

Precast Block Paving

Board Fence Dikes

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A preliminary study of streambank erosion control was conducted with the major emphasis on an extensive literature survey of known streambank protection methods. In conjunction with the survey, preliminary investigations were conducted to identify the mechanisms that contribute to streambank erosion and to evaluate the effectiveness of the most widely used streambank protection methods. The results of the literature survey and the two preliminary investigations are presented herein.

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20. ABSTRACT (Continued).

The text of the "Streambank Erosion Control Evaluation and Demonstration Act of 1974" is presented in Appendix A. A list of commercial concerns that market streambank protection products is provided in Appendix B. Appendix C contains a glossary of streambank protection terminology. A detailed bibliography resulting from the literature survey is provided in Appendix D, and a listing of selected bibliographies related to streambank protection are provided in Appendix E.

FINAL REPORT TO CONGRESS

THE STREAMBANK EROSION CONTROL
EVALUATION AND DEMONSTRATION ACT OF 1974
SECTION 32, PUBLIC LAW 93-251

APPENDIX E
MISSOURI RIVER DEMONSTRATION PROJECTS

VOLUME 2 OF 2

Consisting of

A COMPREHENSIVE SUMMARY REPORT ON TWENTY-EIGHT STREAMBANK EROSION CONTROL DEMONSTRATION PROJECTS ON THE MISSOURI RIVER IN THE THREE REACHES: GARRISON DAM TO LAKE OAHE, FT. RANDALL DAM TO NIOBRARA, AND GAVINS POINT DAM TO PONCA

U.S. ARMY CORPS OF ENGINEERS
December 1981

APPENDIX E

Missouri River Demonstration Projects

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APPENDIX E-3

Section 32 Program Streambank Erosion Control Evaluation and Demonstration Act of 1974

MISSOURI RIVER BETWEEN GAVINS POINT DAM AND PONCA; NEBRASKA AND SOUTH DAKOTA

I - INTRODUCTION

A. PROJECT NAMES AND LOCATIONS.

The Section 32 Authorization specifically designated Gavins Point Dam to Sioux City, Iowa (river mile 811.05 - 732.0, according to 1960 river mileage) as a Section 32 project reach. A general location map is shown in plate 0-1. Previous separate legislation provided the authorization and funding for the Missouri River Kensler's Bend project which resulted in protection measures constructed along both banks from river mile 754.0 to river mile 732.0, a distance of 22 miles. Therefore, the remaining river reach from Gavins Point Dam (river mile 811.05) to Ponca State Park (river mile 754.0) consisted of 57.05 river miles. Twelve demonstration projects were designed for the reach between river miles 811.05 and 754.0; however, only 11 of these projects were built. The twelfth, Mulberry Point, was not constructed because of right-of-way acquisition problems. The names and locations of the twelve project sites are listed in table 3-1. For the purpose of clarity in this report, the Section 32 project reach will hereafter be referred to as the Gavins Point to Ponca reach.

B. AUTHORITY.

The authority for the projects in this reach is Public Law 93-251, Water Resources Development Act of 1974, Section 32, "Streambank Erosion Control Evaluation and Demonstration Act of 1974."

C. PURPOSE AND SCOPE.

The purpose and scope of this report is to describe the bank erosion problems, the types of bank protection used, and evaluate the performance of the 11 Section 32 demonstration projects on the Missouri River, between Gavins Point Dam and Ponca, constructed and monitored by the Omaha District.

Table 3-1

GAVINS POINT DAM TO PONCA, NEBRASKA
PROJECT NAMES, LOCATIONS, AND CONSTRUCTION DATES

Project Name	River Mile Location	Bank Location	Construction Date Started	Construction Date Completed
Cedar County Park I	800.0-797.0	R	7/79	9/79
Cedar County Park II	800.0-797.0	R	5/80	6/80
Goat Island	798.0-795.0	L	8/78	10/78
Vermillion Boat Club	787.0-782.0	L	6/78	10/78
Brooky Bottom Road	786.4-782.9	R	2/76	11/78
Mulberry Point	777.0-776.2	L	Not Constructed	
Mulberry Bend	776.0-774.0	R	1/78	5/80
Vermillion River Chute	772.0-769.5	L	2/77	7/80
Ryan Bend	773.0-776.0	R	1/78	6/78
Ionia Bend	763.0-758.0	R	8/78	11/78
Elk Point I	756.5-754.0	L	9/79	6/80
Elk Point II	756.5-754.0	L	5/80	8/80

D. PROBLEM RÉSUMÉ.

Natural constraints on channel meandering have been imposed on the Missouri River by the geomorphic configurations of the narrow valley in those reaches upstream from Gavins Point. The wide flood plain characteristics of the reach from Gavins Point Dam to Ponca have allowed the

river channel more freedom to migrate. The classical alluvial river meander pattern has been established in this reach and the meander scars indicate continuous river migration within a meander belt of 1 to 3 miles in width. Plates 0-3 through 0-10 show the river channel locations for the years 1980, 1944 and 1974 in this reach.

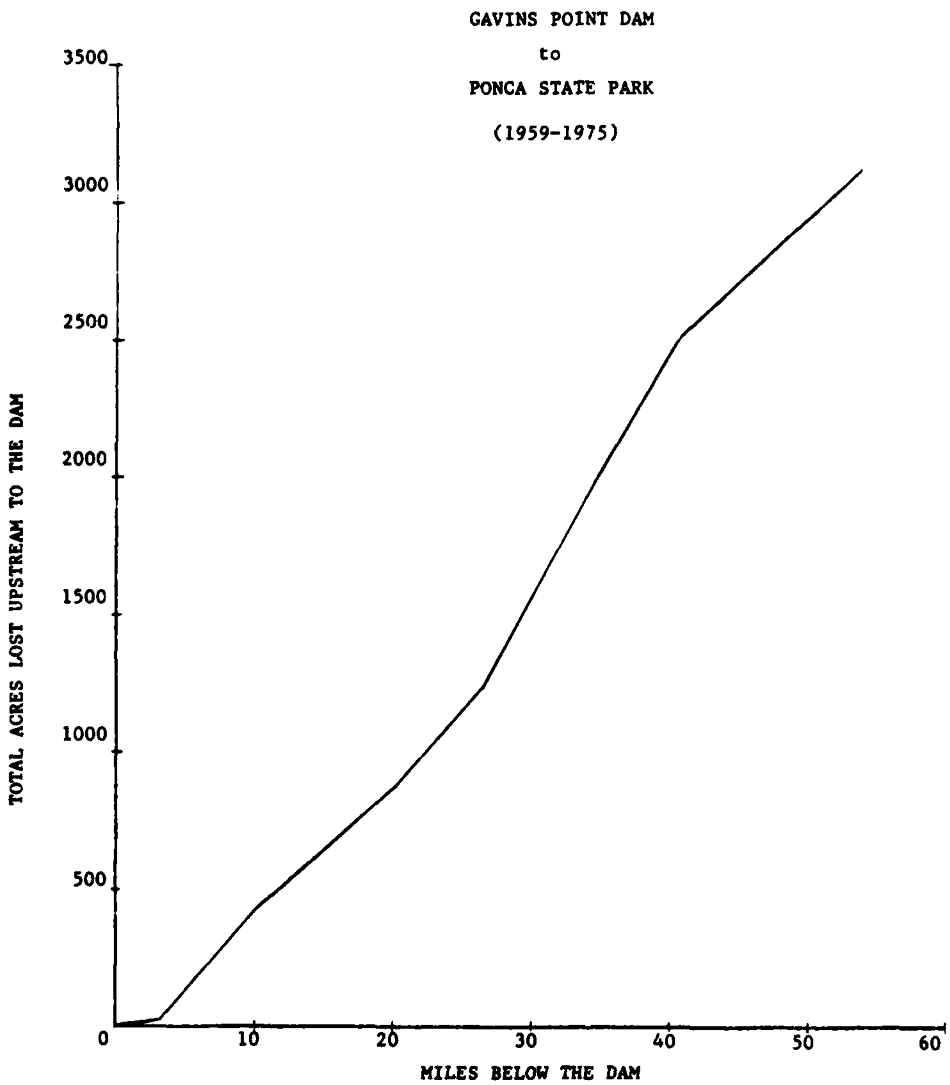
The most salient characteristic of the reach is that of severe erosion. This river reach has demonstrated higher erosion losses than either the Garrison to Oahe reach or the Fort Randall to Niobrara reach. Figure 3-1 illustrates the accrued acreage loss comparisons in these three reaches. The reach from Gavins Point Dam to Ponca has 57.5 miles of open river and approximately 106.3 miles of erodible bankline. A total of 3,760 acres have been lost between 1955 and 1975. This averages 3.26 acres per river mile per year.

It would be unrealistic to assume, however, that uniform erosion takes place. Within this reach the erosion of land in any one year is usually concentrated over a few thousand feet of bankline in one or more locations. These locations of active erosion shift from place to place with time. Over the years every stretch of erodible bankline is potentially subject to active erosion. The continuing threat of high bankline erosion rates is a particular problem and has a detrimental impact on river development.

Prior to the completion of Gavins Point Dam, erosion losses were generally offset by accretion of equally high and fertile lands. The irretrievable loss of fertile high ground is aggravated by the loss of

Figure 3-1

Acreage Loss Comparisons



the accretion/erosion cycle. Construction of Gavins Point Dam eliminated the incoming sediment load to the reach by trapping the sediment from the upstream reach. As a result of this entrapment, the dam releases clear water thereby virtually eliminating the accretion of high overbank areas. Downstream from the dam sediment is of two types: suspended sediments and bed load. Suspended sediments are obtained from runoff and the banks while bed load material is scoured from the bed and sand bars. Although the average water surface area and average depths are remaining relatively constant, the river is tending to braid more and the number of channels is gradually increasing. This process, unless halted, would eventually transform the present river into a wide area of sand bars and channels, occupying an increasing proportion of the valley width between bluffs.

Site selections for the installation of erosion protection demonstration projects were based on previously documented complaints and field reconnaissance as well as the following criteria: consideration for comparative erosion rates; land use; environmental factors (i.e., site adaptability to various potential erosion control measures); and availability of a qualified local governmental entity willing to provide sponsorship for erosion control demonstrations.

II - HISTORICAL DESCRIPTION

A. GENERAL DESCRIPTION

1. GEOMORPHOLOGY

a. **Physiography**. This reach of the Missouri River forms the border between the Western Lakes Section and the Dissected Till Plains Section of the Central Lowland Physiographic Province. The present course of the Missouri River was developed in recent geologic time. This course represents the river's adjustment to flow along the edge of one of the advances of the Wisconsin ice sheet. This present course of the river coincides with the farthest southward advance of the Wisconsin ice sheet and forms the dividing line between the two physiographic sections. Glacial deposits control the topographic distinctions in the central Lowland Province but not the underlying sedimentary rocks. The characteristic features of the physiographic division in the area resulted from glaciation of different periods. In the south, preglacial features were completely buried, producing a surface with relatively low relief as a result of the advance of the Kansan ice sheet. The advance of the Kansan ice sheet created the Dissected Till Plains. This flat, glacial till plain is submature to mature in its erosion cycle and has a relief between one hundred and three hundred feet. A mantle of loess measuring a few feet thick overlies the till. To the north lies the Western Young Drift Section. This till has the characteristic distinguishing features of young glacial drift (Wisconsin) such as immature drainage and marginal moraines. These features readily differentiate the Western Young Drift Section from the Dissected Till Plains Section.

b. **Topography**. Downstream of Gavins Point Dam, the valley widens rapidly. From Yankton, South Dakota to Sioux City, Iowa, the valley

is characterized by very wide flood plains, four miles across at Vermillion and eight miles across near Ponca, Nebraska. The bluffs are still steep, but are only 200-300 feet high. They lack the "bad-lands" topography characteristic of the trench further north and west. The gradient of the river along this reach is approximately one foot per mile.

A well developed dendritic pattern of drywash tributaries and consequent streams drains the bluffs along the right side of the river valley. The drainage pattern indicates a submature to mature erosion cycle. The drainage features on the left side of the river valley are in contrast to those on the right side. The pattern of the tributary streams on the left bank is less extensive and the streams are young in their erosion cycle. Depth of erosion is not extensive when compared to that of the right side of the valley. Several of these drainages on the left bank have cut deep channels across the flood plain and empty the sediments directly into the river, quite unlike those on the right bank.

c. **Geology**. The rock strata along this reach are essentially flat lying. The exposed formations are cretaceous sedimentary beds which dip gently towards the west. There are five rock formations exposed between Gavins Point Dam and Ponca, Nebraska. The stratigraphic sequence in ascending order is the Dakota, Graneros, Greenhorn, Carlile and Niobrara Formations. Plate 0-2 shows a geologic profile at Gavins Point Reservoir.

The Dakota formation is primarily sandstone and is usually referred to as the Dakota sandstone. The sandstone is coarse, sometimes loosely cemented, tan to rusty in color. It is laminated with clay and iron-oxide concretions. Layers of shale are common, especially in the upper part and an occasional lignite bed can be found.

The first outcrop of the Dakota sandstone is at Ponca State Park in Nebraska. There, about 7½ feet are exposed above the river water and it extends for about 1,000 feet along the shore. The contact with the overlying Graneros shale cannot be seen because of a terrace of alluvium 21 feet high above the water. Downstream of Ponca the Dakota sandstone is more prominent. It is the oldest sedimentary rock exposed in the Missouri Valley from northeastern Nebraska to North Dakota.

The Graneros formation consists mainly of fi -grained, dark colored shale which is more or less sandy at the base. Concretions of iron carbonate occur at different horizons and iron pyrite is more or less abundant throughout the shale. In the vicinity of Ponca where the basal member of the formation consists of sandstone there is a thin seam of lignite. The Graneros shale varies considerably within short distances in both character and thickness. It is from 65 to 105 feet thick and weathers into vertical cliffs.

The Graneros formation lies on the Dakota sandstone formation and is the lowest formation of the Benton group. The outcrops are confined mainly to the bluffs of the larger streams which first occur on the Nebraska side across from Elk Point in the vicinity of Ponca, Nebraska.

The Greenhorn formation comprises a thin but very distinctive series of beds of hard impure limestone with a thickness of about 32 feet. It consists of a basal member 8 to 10 feet thick of bluish chalky limestone; a medial member of hard, thin-bedded limestone about 12 feet thick containing fossils in great abundance and interstratified with chalky shale; and a top member of bluish limestone 4 to 8 feet thick. The lime commonly occurs in large blocks divided by distinct but irregular joints. The Greenhorn formation is the middle member of the Benton group and outcrops on the south side of the Missouri River in the bluffs in Nebraska in the reach from Elk Point to Ponca.

The Carlile shale consists of silky, sandy, or sometimes limy shale with sandstone interbedded in places. The Carlile shale formation underlies the river but is not exposed in most places since it is buried by the valley fill deposits. Between Yankton and Vermillion, however, the river cuts deeply enough to expose the Carlile shale. Along this reach, the Carlile shale outcrops at the lower elevation of the bluffs and the Niobrara chalk outcrops at the higher elevations. Between Vermillion and Elk Point, the Carlile shale is the most prominent formation.

The Niobrara formation is a dark gray, argillaceous, soft but firm chalk and chalky shale which contains many microscopic shells of Foraminifera and Ostracoda. When closely examined, the chalk has a salt-and-pepper appearance due to light colored shell and clastic fragments in a darker groundmass. The color changes to a buff or light gray when the formation is weathered. Along the upstream portion of this reach, in the vicinity of Gavins Point Dam, the Niobrara chalk formation is most prominent and it forms the walls of the Missouri River Trench.

The overburden materials are composed of two basic types depending on the origin, glacial deposits and river valley deposits. The glacial deposits are heterogenous mixtures of silt, clay, sand and gravel with numerous boulders dispersed in them, and are generally found at the higher elevations. Small lenses of sand and gravel are found in the general mixture of glacial drift. Several thick layers of sand and gravel also occur within the drift. These layers are probably the result of outwash from the edge of the ice sheet and inwash from the west. The thickness of these glacial deposits varies from 0 to 20 feet in the vicinity of Gavins Point. The river valley deposits are chiefly composed of sand and gravel, interbedded with silt and clay. Information from borings indicates that downward cutting of the valley and later filling extends to depths of about 150 feet below the present river level. Table 3-2 presents representative soil survey data at the demonstration project sites.

Project Name & Location	Soil Series & Symbol	Topography	Upper Bank Slope	Depth (Inches)	USDA Texture	Classification: UNIFIED	Classification: AASHTO	Percentage Passing Sieve Number: No. 4 (4.7 mm)	No. 10 (2.0mm)	No. 40 (0.42mm)	No. 200 (0.074 mm)	Drainage	Permeability (In/Hr)	Available Moisture Capacity (In/Inches)	Liquid Limit (Percent)	Plasticity Index (Percent)	Shrink-Swell Potential	General Characteristics
Brunky Bottom Road (Cedar County, NE)	ALBATON Ac	Bottomlands	0-1%	0-7	Silty Clay	CH	A-7		100	95-100	95-100	Poor	0.06-0.2	0.10-0.14	55-75	35-55	High	High compressibility;
				7-60	Silty Clay	CH	A-7		100	95-100	95-100	Poor	0.02-0.2	0.08-0.12	60-85	40-60	High	Medium to low shear strength; Fair to poor compaction characteristics
	HAYNIE Ha	Bottomlands	0-2%	0-60	Silty Loam, Very Fine Sandy Loam	ML, CL	A-4, A-6	100	100	85-100	70-100	Well-Drained	0.6-2.0	0.21-0.23	30-40	5-15	Low	Low shear strength; Susceptibility to piping; High susceptibility to erosion
	MODALE Mo	Bottomlands	0-2%	0-22	Silty Loam	CL, ML	A-4, A-6	100	100	95-100	70-90	Moderately	0.6-2.0	0.21-0.23	25-40	8-18	Moderate	Low shear strength;
				22-60	Silty Clay, Clay	CH	A-7	100	100	95-100	95-100	Well-Drained	0.6-0.2	0.11-0.13	65-85	40-60	High	High susceptibility to piping; High susceptibility to erosion
	SARPY Sc	Bottomlands	0-2%	0-8	Silty Clay	CH	A-7	100	100	100	100	Excessively Drained	0.06-0.2	0.13-0.15	60-8	35-50	High	Susceptible to piping; Medium to high susceptibility to piping:
				8-60	Loamy Fine Sand, Fine Sand	SM	A-2	100	100	60-80	15-35	Excessively Drained	6.0-20	0.15-0.09	0	0	Low	Medium compacted permeability
Cedar County Park Phase I and II (Cedar County, NE)	GRABLE Gr	Bottomlands	0-2%	0-7	Very Fine Sandy Loam	CL, ML	A-4, A-6	100	100	80-95	50-75	Well-Drained	0.6-2.0	0.22-0.24	25-40	8-20	Low	Low shear strength; Susceptible to piping
				7-24	Silt Loam, Very Fine Sandy Loam	CL, ML	A-4, A-6	100	100	80-95	50-75	Well-Drained	0.6-2.0	0.20-0.22	25-40	8-20	Low	
				24-60	Fine Sand, Loamy Sand	SM, SM-SC SP-SM	A-2, A-3	100	100	65-80	5-35	Well-Drained	6.0-20	0.02-0.07	20	NP-5	Low	
	HAYNIE Ha	Bottomlands	0-2%	0-60	Silty Loam, Very Fine Sandy Loam	ML, CL	A-4, A-6	100	100	85-100	70-100	Well-Drained	0.6-2.0	0.21-0.23	30-40	5-15	Low	Low shear strength; Susceptible to piping; High susceptibility to erosion
	PERCIVAL Pe	Bottomlands	0-2%	0-7	Silty Clay	CH or MH	A-7	100	100	95-100	95-100	Slow Drainage	0.06-0.2	0.10-0.14	60-85	30-60	High	Low shear strength; High compressibility
				7-25	Silty Clay	CH or MH	A-7	100	100	95-100	95-100	Slow Drainage	0.06-0.2	0.10-0.12	60-85	30-60	High	
				25-60	Stratified Fine Sand and Loamy Fine Sand	SM or SP-SM	A-2 or A-3	100	100	80-95	5-30	Slow Drainage	6.0-20.0	0.06-0.08	25	0-5	Low	
	SARPY Sr	Bottomlands	0-2%	0-8	Silty Clay	CH	A-7	100	100	100	100	Excessively Drained	0.06-0.2	0.13-0.15	60-8	35-50	High	Susceptibility to piping; Medium to high susceptibility to piping.
				8-60	Loamy Fine Sand, Fine Sand	SM	A-2	100	100	60-80	15-35	Excessively Drained	6.0-20	0.15-0.09	0	0	Low	Medium compacted permeability
Elk Point Phase I and II (Union County, SD)	ALBATON Ac	Bottomlands	0-1%	0-7	Silty Clay	CH	A-7		100	95-100	95-100	Poor	0.06-0.2	0.10-0.14	55-75	35-55	High	High compressibility;
				7-60	Silty Clay	CH	A-7		100	95-100	95-100	Poor	0.02-0.2	0.08-0.12	60-85	40-60	High	Medium to low shear strength; Fair to poor compaction characteristics
	HAYNIE Ha, Hb	Bottomlands	0-2%	0-21	Silty Loam	ML, CL	A-6 or A-7	100	100	85-100	70-100	Well-Drained	0.6-2.0	0.17-0.20	30-50	10-25	Low	Medium to low shear strength;
				21-60	Very Fine Sandy Loam	ML or CL	A-4 or A-6	100	100	85-100	60-100	Well-Drained	0.6-2.0	0.15-0.17	15-30	5-20	Low	Medium susceptibility to piping; Fair compaction characteristics
	MODALE Mb	Bottomlands	0-2%	0-11	Silty Loam	CL	A-6	100	100	95-100	70-90	Moderate to Well-Drained	0.6-2.0	0.17-0.20	25-40	10-20	Moderate	Low shear strength;
				11-24	Very Fine Sandy Loam	ML or CL	A-4 or A-6	100	100	85-95	60-90		0.6-2.0	0.15-0.17	15-30	5-15	Moderate	High susceptibility to piping; High susceptibility to erosion
				24-60	Silty Clay	CH or MH	A-7	100	100	95-100	95-100		0.6	0.08-0.12	65-85	25-60	High	
	ONAWA Ob	Bottomlands	0-1%	0-7	Silty Clay	CH or MH	A-7	100	100	95-100	95-100	Moderate	0.06-0.2	0.10-0.14	50-85	25-60	High	Low shear strength,
				7-25	Silty Clay	CH or MH	A-7	100	100	95-100	95-100	Moderate	0.06-0.2	0.08-0.12	50-85	25-60	High	High compressibility;
				25-60	Silty Loam	CL or ML	A-4, A-6 or A-7	100	100	95-100	85-100	Moderate	0.6-2.0	0.17-0.20	30-50	5-30	Moderate	Fair compaction characteristics
	SARPY SaA	Bottomlands	0-4%	0-9	Loamy Fine Sand	SM	A-2	100	100	60-80	15-35	Excessively Drained	6.0	0.05-0.09	0	0	Low	Susceptible to piping
				9-60	Loamy Fine Sand, Fine Sand	SM	A-2	100	100	60-80	15-35	Excessively Drained	6.0	0.05-0.09	0	0	Low	

Table 3-2
Gavins Point to Ponca
Section 32 Soil Data

Project Name & Location	Soil Series & Symbol	Topography	Upper Bank Slope	Depth (Inches)	USDA Texture	Classification USCS	Classification AASHTO	Percentage Passing Sieve Number No. 4 (4.7 mm)	No. 10 (2.0mm)	No. 40 (0.42mm)	No. 200 (0.074 mm)	Drainage	Permeability (In/Hr)	Available Moisture Capacity (In/Inches)	Liquid Limit (Percent)	Plasticity Index (Percent)	Shrink-Swell Potential	General Characteristics
Goat Island (Yankton County, SD)	BLAKE Bc	Bottomlands	0.2%	0-17	Silty Clay Loam	CL	A-6, A-7	100	100	95-100	85-100	Poor	0.2-2.0	0.19-0.22	30-50	10-25	Moderate	Susceptible to piping
				17-53	Silty Loam, Silty Clay Loam	ML, CL	A-4, A-6 A-7	100	100	90-100	85-100	Poor	0.2-2.0	0.19-0.22	30-45	5-20	Moderate	
				53-60	Loamy, Very Fine Sand	SM, ML, SM-SC, CL-ML	A-4	100	100	85-95	40-65	Poor	2.0-6.0	0.11-0.15	25	NP-5	Low	
	HAYNIE Hn, Hb	Bottomlands	0-2%	0-21	Silty Loam	ML, CL	A-6 or A-7	100	100	85-100	70-100	Well-Drained	0.6-2.0	0.17-0.20	30-50	10-25	Low	Medium to low shear strength; Medium susceptibility to piping; Fair compaction characteristics
				21-60	Very Fine Sandy Loam	ML or CL	A-4 or A-6	100	100	85-100	60-100	Well-Drained	0.6-2.0	0.15-0.17	15-30	5-20	Low	
	LUTON Ld	Bottomlands	0-1%	0-16	Silty Clay	CH	A-7	100	100	95-100	95-100	Poor	0.6	0.12-0.14	60-85	35-60	High	Low shear strength; High compressibility; Poor compaction characteristics
				16-24	Silty Clay, Clay	CH	A-7	100	100	95-100	95-100	Poor	0.6	0.12-0.14	60-85	35-60	High	
				24-60	Silty Clay	CH	A-7	100	100	95-100	95-100	Poor	0.6	0.11-0.13	60-85	35-60	High	
Ionia Bend (Dixon County, NE)	HAYNIE Hn	Bottomlands	0-2%	0-60	Silty Loam, Very Fine Sandy Loam	ML, CL	A-4, A-6	100	100	85-100	70-100	Well-Drained	0.6-2.0	0.21-0.23	30-40	5-15	Low	Low shear strength; Susceptibility to piping; High susceptibility to erosion
	GRACEVILLE Gb	Terraces	0-2%	0-34	Silty Clay Loam	CL or ML	A-7 or A-6	100	95-100	80-95	70-90	Moderately Well-Drained	0.6-2.0	0.19-0.22	35-50	10-30	Moderate	Fair to good stability and compaction char. Medium to low shear strength;
				34-52	Silty Clay Loam	CL or ML	A-7 or A-6	100	90-100	80-90	75-85	Moderately Well-Drained	0.6-2.0	0.17-0.20	35-50	10-30	Moderate	
				52-60	Gravelly Sand	SM, GM SM-SM, or SM-SC	A-1 or A-2	40-80	30-70	20-50	5-30	Moderately Well-Drained	6.0-20.0	0.03-0.06	25	NP-5	Low	
	ONAWA On	Bottomlands	0-2%	0-21	Silty Clay	CH	A-7	100	100	95-100	95-100	Poor to Moderate	0.06-0.2	0.12-0.14	60-85	40-60	High	Low shear strength; High compressibility
				21-60	Silty Loam Very Fine Sandy Loam, Loam	CL, ML, CL-ML	A-4, A-6	100	100	95-100	85-100	Poor to Moderate	0.6-2.0	0.20-0.22	25-40	5-20	Moderate	
	SARPY Sa	Bottomlands	0-2%	0-7	Loamy Fine Sand	SM	A-2	100	100	60-80	15-35	Excessively Drained	6.0-20	0.05-0.09	0	0	Low	Susceptible to piping
				7-60	Loamy Fine Sand, Fine Sand	SM	A-2	100	100	60-80	15-35	Excessively Drained	6.0-20	0.05-0.09	0	0	Low	
Mulberry Bend (Dixon County, NE)	ALBATON Ab	Bottomlands	0-2%	0-7	Silty Clay	CH	A-7	100	100	95-100	95-100	Poor	0.06-0.2	0.11-0.13	60-85	40-60	High	High compressibility; Medium to low shear strength; Fair to poor compaction characteristics
				7-60	Silty Clay, Clay	CH	A-7	100	100	95-100	95-100	Poor	0.06-0.2	0.11-0.13	60-85	40-60	High	
	KENNEBEC Ke	Bottomlands	0-1%	0-15	Silty Loam	CL, ML CL-ML	A-6, A-7	100	[illegible]	95-100	90-100	Moderately Well-Drained	[illegible]	0.22-0.24	30-50	10-20	Moderate	Low shear strength, High compressibility; Fair to poor compaction characteristics
				15-60	Silty Loam, Silty Clay Loam	CL, ML	A-6, A-7	100	100	95-100	90-100		0.6-2.0	0.20-0.22	30-50	10-20	Moderate	
Ryan Bend (Dixon County, NE)	ALBATON Ab	Bottomlands	0-1%	0-7	Silty Clay	CH	A-7	100	100	95-100	95-100	Poor	0.06-0.2	0.11-0.13	60-85	40-60	High	High compressibility, Medium to low shear strength; Fair to poor compaction characteristics
				7-60	Silty Clay, Clay	CH	A-7	100	100	95-100	95-100	Poor	0.06-0.2	0.11-0.13	60-85	40-60	High	
	HAYNIE Hn	Bottomlands	0-2%	0-60	Silty Loam, Very Fine Sandy Loam	ML, CL	A-4, A-6	100	100	85-100	70-100	Well-Drained	0.6-2.0	0.21-0.23	30-40	5-15	Low	Low shear strength; Susceptible to piping; High susceptibility to erosion
	ONAWA On	Bottomlands	0-2%	0-21	Silty Clay	CH	A-7	100	100	95-100	95-100	Poor to Moderate	0.06-0.2	0.12-0.14	60-85	40-60	High	Low shear strength; High compressibility
				21-60	Silty Loam Very Fine Sandy Loam, Loam	CL, ML, CL-ML	A-4, A-6	100	100	95-100	85-100	Poor to Moderate	0.6-2.0	0.20-0.22	25-40	5-20	Moderate	
	SARPY SdB	Bottomlands	0-6%	0-7	Fine, Sand	SM	A-2	100	100	60-80	15-35	Excessively Drained	6.0-20	0.05-0.09	0	0	Low	Susceptible to piping
				9-60	Loamy Fine Sand, Fine Sand	SM	A-2	100	100	60-80	15-35	Excessively Drained	6.0-20	0.05-0.09	0	0	Low	
	STORLA St	Bottomlands	0-2%	0-14	Loam	ML or CL	A-4 or A-6	100	95-100	75-95	50-80	Poor	0.6-2.0	0.18-0.20	30-40	5-20	Moderate	Fair to poor stability and compaction char. Medium to high compressibility
				14-31	Loam	ML, CL, or SC	A-4 or A-4	95-100	85-100	60-95	35-80	Poor	0.6-2.0	0.13-0.15	25-40	5-20	Moderate	
				31-60	Gravelly Sand	SM, SM-SC, SP-SM or SM-SM	A-1 or A-2	60-90	45-70	20-60	5-30	Poor	6.0-20.0	0.03-0.06	25	0-5	Low	

Table 3-2
Gavins Point to Ponca
Section 32 Soil Data (Cont'd)

2. **VALLEY LAND USE**. Landward from the high river banks the use of valley lands is predominently agricultural. Much of the remaining forest in the river bottoms is as yet uncleared adjacent to the river banks. Stimulated by the virtual elimination of flooding, there is a continuing trend in all the reaches for private homes and recreational facilities to be constructed along the banks.

3. **HYDROLOGIC AND METEOROLOGIC CHARACTERISTICS**. The climate of the Gavins Point Dam to Ponca reach of the Missouri River is classified as sub-humid. In an average year the annual precipitation totals 25 inches. June normally is the wettest month with an average of 4.5 inches. January is normally the driest month with an average of .5 inch.

Daily maximum temperatures for July, the warmest month, average 88°F, with daily minimum temperatures averaging 63°F. During January, the coldest month, the daily maximum temperatures average 29°F, while the daily minimum temperatures average 8°F. The average length of the freeze-free period is 162 days, from April 29 to October 8. Although there is much runoff over the frozen or partially frozen soil as the snow melts in the spring, the flood peaks move slowly in the gently sloping river channels. The James River has a slope of only 4 to 6 inches per mile. The maximum discharge recorded on the James River near Scotland, South Dakota, was 15,200 c.f.s. on April 3, 1962. The maximum discharge recorded on the Vermillion River near Wakonda, South Dakota, was 9,880 c.f.s. on April 8, 1969. The projected 100-year release from Gavins Point Dam is 80,000 c.f.s.

4. **EXISTING CHANNEL CONDITIONS**. The Gavins Point to Ponca reach of the Missouri River is essentially a meandering stream regulated by Gavins Point Dam. This reach consists of 57.5 river miles, of which approximately 8.7 bankline miles of the reach are in bluff contact. At all projects except Gavins Point, hourly release rates may be varied widely to meet varying power loads. Variations in release rates at the

Gavins Point project are primarily subject to limitations to restrict stage fluctuations downstream so navigation will not be adversely affected. Essentially all river stages in the open river reach downstream of the dam have been confined within the channel below the high river banks.

5. **ENVIRONMENTAL CONDITIONS** The plant and animal community in the Gavins Point to Ponca reach of the Missouri River is quite diverse. Species from at least 27 families of plants, 17 families of mammals, 29 families of birds, 10 families of reptiles and amphibians, 15 families of fishes, and 45 families of insects occur, or are expected to occur, in the corridor. The abundance of some of the individual species of these families is discussed in the paragraphs below.

a. **Terrestrial Habitat and Species.** Terrestrial habitat in this reach consists of agricultural land and natural vegetation. Most agricultural land is used for corn, oats, soybeans or alfalfa. Those lands planted with corn provide an important source of food for migrating ducks and geese. The combination of the corn fields, the constant ice/water patterns of the river during winter months, and the slower current speed of the river reach (relative to the channelized reach below Ponca State Park) provide the essential wintering elements for tens of thousands of various waterfowl, most of which are mallard ducks. Natural terrestrial habitat in this reach consists mainly of five different habitat types: elm-oak, cottonwood-dogwood, willow-cottonwood, sand dune, and sandbar.

The elm-oak habitat occurs on the Nebraska side of the river reach which consists of steep topography and a wide variety of trees. The most important of these are bur oak, box elder, slippery elm, and eastern red cedar. Much of the understory has been grazed, therefore, the value of the habitat for most forms of wildlife has been reduced. The oak mast, however, does provide much food for big game and fox squirrels.

Cottonwood-dogwood habitat occurs on the large islands in the river and on both sides of the river along the high banks. Cottonwood is generally the only mature tree present in this habitat type. Slippery elm, green ash, and box elder are common young trees present. Red osier dogwood is the dominant shrub species. This habitat provides good to excellent cover and food for most of the wildlife species inhabiting the river reach, especially white-tailed deer, mule deer, and various species of birds.

Willow-cottonwood habitat occurs predominantly on the islands and the lower terraces adjacent to the river. This habitat consists of an interspersion of open areas with herbaceous growth, rushes, or horsetail; chutes with cattail peripheries; patches of willow and tall cottonwood; and dense thickets of willows. This habitat also provides much food and cover for most of the wildlife species inhabiting the river reach. It is especially excellent habitat for big game and receives much use by white-tailed deer. The habitat also provides excellent cover for ring-necked pheasants and mourning doves.

Sand dune habitat is interspersed between the other habitats in the river reach. Distribution of vegetation in this habitat is variable. The habitat includes areas of sand with no vegetation; areas with considerable grass/forb cover; and areas of sand with tall cottonwoods only or with tall cottonwoods and an understory of willows, cottonwood saplings, or alfalfa. Any combination of the three may also occur. Terrestrial birds make moderate use of this habitat; sand-dwelling reptiles, such as hognose snakes and great plains toads, are numerous.

Sandbar habitat occurs in or adjacent to the river and is essentially nonvegetated. This habitat provides important resting areas for migrating waterfowl and feeding locations for breeding shorebirds such as killdeer, upland sandpipers, and spotted sandpipers. It also provides important breeding sites for piping plovers and interior least terns.

b. **Aquatic Habitat and Species**. Aquatic habitat in the river reach consists mainly of seven different habitat types: main channel, main channel border, chute, backwater, marsh, sandbar, and pool.

Main channel habitat in the river reach is that part of the river with the swiftest current. Surface velocities in this habitat usually exceed 3 feet per second. Depths in this habitat, as well as in others where there is considerable current, constantly change because of the shifting sand bed of the river. The most abundant species in this habitat are channel catfish and paddlefish.

Main channel border habitat is that part of the river adjacent to the main channel shoreline; it is usually no more than 40 feet wide. It is usually bordered by high, friable banks and contains large quantities of logs, stumps, and other debris. Gizzard shad, carp, river carp sucker, channel catfish, shorthead redhorse, gold eye, blue sucker, and sauger are the most abundant species in this habitat.

Chute habitat includes all side channels from the main channel of the river in which there is current during most of the year. Fish species found in this habitat are basically the same as those in the main channel border habitat.

Backwater habitat consists of areas connected to the river that have little or no current. These areas are usually formed when the upstream end of a chute is closed by the lowering of water levels. This habitat is usually surrounded by marsh. It contains the largest number of fish species that exhibit a preference for a particular habitat type. Gar, buffalo, gizzard shad, carp, northern pike, red shiner, darters, yellow perch, and members of the sunfish family are the dominant users of this habitat type.

Marsh habitat in the river reach exists in flooded lowland areas adjacent to backwaters and chutes. Water depths in the marshes are highly responsive to changes in releases from Gavins Point Dam and fluctuate from 3 feet to complete dryness. Many species of fish use marsh habitat as a spawning and nursery ground. The dominant species are carp, yellow perch, emerald shiner, blue gill, green sunfish, Johnny darter, red and sand shiners, river carpsucker, gizzard shad, and smallmouth and bigmouth buffalo. This habitat is also excellent for muskrat, mink, diving ducks, such as the lesser scaup, migrating mallards, pintails, blue-winged teals, and other waterfowl. Other birds which use this habitat are great blue herons, red-winged blackbirds, yellow-headed blackbirds, common grackles, Forster's terns, and American coots. Turtles and frogs are also abundant in this habitat.

Sandbars are one of the main features of the river reach. Associated with these bars is what is known as sandbar aquatic habitat, which includes those areas immediately adjacent to exposed bars where the water depth is 5 feet or less. Sandbar habitat is used primarily as nursery grounds for emerald and sand shiners, river carpsucker, shorthead redhorse, yellow perch, sauger, carp, and smallmouth and bigmouth buffalo.

c. **Federally Listed Endangered Species**. The only Federally listed endangered species that is currently present in the river reach is the bald eagle. This species occurs as a winter resident during mild winters. It utilizes the many large cottonwood trees adjacent to the river's edge as perch sites while feeding. It also utilizes the large cottonwood trees that are well protected from the wind and have stout, horizontal branches extending over open areas for roosting. The abundance of this species in the river reach is highly dependent on the severity of the winter; the sighting of one dozen bald eagles in the river reach on a winter's day is not uncommon. The endangered whooping crane and peregrine falcon also occur in the river reach occasionally during their migration.

d. **State-Listed Endangered Species - Nebraska.** The pallid sturgeon and the interior least tern are two species that are on the Nebraska state list of threatened species and are known to inhabit the river reach. The pallid sturgeon prefers a habitat of unpolluted water, a firm sandy bottom, and a strong current. The last documented occurrence of this species in the river reach was in 1979. The interior least tern arrives in the river reach in April and departs in August. Its preferred nesting habitat is the large, low, open sandbars in the river. The number of breeding colonies is currently being investigated by the Nebraska Game and Parks Commission. The Commission estimates at this time that the river reach supports the largest number of breeding colonies in the state.

e. **State-Listed Endangered Species - South Dakota.** Fish and wildlife species uncommon in South Dakota, on the South Dakota list of threatened and endangered species, and known to inhabit the river reach are presented in table 3-3. Also presented in table 3-3 are the species preferred habitat and data regarding the most recent recorded observation of the species.

Table 3-3

THREATENED AND ENDANGERED WILDLIFE SPECIES THAT OCCUR IN THE CORRIDOR

Species	Preferred Habitat	Current Observation Data
Osprey	Large cottonwood trees	Regularly migrate through corridor
Eastern Hognose snake	Sand dune	Fairly common in corridor
Spiny soft shell turtle	Sandbar/pool	Occasionally observed
False map turtle	Backwaters/snags	Fairly common in corridor
Sicklefin chub	Large turbid rivers	1962 - 5 miles south of Yankton
Sturgeon chub	Large rivers	1962 - Yankton County
Pallid sturgeon	Main channel/pool	1978 - Yankton County
Interior least tern	Large sandbars	Fairly common in corridor

B. DEMONSTRATION PROJECT

1. HYDRAULIC CHARACTERISTICS

a. **Channel Widths and Depths**. The floodplain width (distance between high banks) averages over 2,000 feet and varies from 600 feet to over 1 mile in some areas. The main channel widths ranged from 400 feet to about 4,200 feet with main channel depths averaging between 4 feet and 20 feet. The main channel widths and depths may vary considerably depending upon the discharge from Gavins Point Dam.

b. **Normal Water Surface**. The Normal Water Surface (NWS) in this reach represents the estimated water surface profile for a steady state discharge of 35,000 c.f.s. from Gavins Point Dam. This flow represents the flow equalled or exceeded 50 percent of the time, since closure of the dam, during the open-water season from April through October, as shown on plate 0-14. The NWS this represents is a key elevation for structure design. Further, the NWS provides a practical datum plane in the field to effectively monitor construction operations and to periodically evaluate completed structures. Plate 0-13 shows the Normal Water Surface for Gavins Point Dam to Ponca, Nebraska reach.

c. **Sediment Characteristics**. The sediment characterisics of the Gavins Point Dam to Sioux City, Iowa reach are typical of a reach in a state of degradation in which the upstream reservoir traps virtually all incoming sediment load. Sediment load in the downstream reaches consists of bed material load derived from the river bed, and bed material and wash load derived from eroded river banks and tributary inflows. The average annual measured load ranges from 0 downstream of Gavins Point Dam to 10,920,000 tons per year at the Sioux City, Iowa sediment measuring station. Of this, aproximately one million tons per year is contributed by the James and Big Sioux Rivers. Variation in the annual sediment loads from 1956 to 1971 ranged from 6,522,800 tons in 1961 to 23,682,700 tons in 1971. A tabulation of the average

annual measured load at Sioux City since closure of Gavins Point Dam is given in table 3-4. Over the first 3 miles below the dam the channel bed is armored with a layer of relatively nonmoveable coarse gravels and cobbles with material sizes ranging from 1/4 to 3 inches in nominal diameter and generally laying in a single layer overlying subsurface sediments comprised of medium to coarse sands. From there donwstream the bed surface is composed of coarse to fine grained sediments with the D50 grain sizes averaging about 2.0 mm at the upstream end of the reach and decreasing exponentially to a value of 0.35 mm fifty miles downstream. The D10, the D50 and the D90 particle size gradations of the bed material, at the downstream end of the degradation reach near Sioux City, Iowa are 0.085 mm, 0.14 mm, and 0.25 mm. Approximately 32 percent of the measured suspended load is silt and clay while the remaining 68 percent is comprised of suspended sand size particles.

Table 3-4

AVERAGE ANNUAL MEASURED SEDIMENT LOAD @ SIOUX CITY, IOWA SEDIMENT MEASURING STATIONS

Year	Sediment (Tons/Year)
1956	14,148,090
1957	8,047,150
1958	7,306,160
1959	10,642,000
1960	14,073,400
1961	6,522,800
1962	12,408,400
1963	6,957,180
1964	7,949,870
1965	9,226,770
1966	11,791,220
1967	13,336,260
1968	11,376,700
1969	17,839,970
1970	14,871,960
1971	23,682,700

d. **Degradation.** Degradation in this reach, since the closure of Gavins Point Dam in 1955, ranges from 8.3 feet immediately below the dam to about 3.8 feet at Sioux City. Degradation in the reach immediately below the dam is currently averaging about 0.18 feet per year.

e. **Streambank Erosion Rates.** Controlled aerial photographs obtained at several different times were analyzed to determine the high bank losses experienced in this river reach due to erosion. Significant erosion losses along islands, low elevation sand bars, sloughs, and chutes have also been noted but not quantified. Results of these analyses are shown in table 3-5. Erosion rates in acres/mile/year by river mile are displayed graphically on plates 0-11 and 0-12. High bank erosion rates correlated to distances downstream from Gavin's Point Dam are shown in table 3-6.

Table 3-5

MISSOURI RIVER HIGH BANK EROSION RATES
GAVINS POINT DAM TO PONCA STATE PARK

Period	Length of Time (Years	Total Erosion Loss (Acres)	Reach Erosion Rate (Acres/Year)
1930-1945	15.0	3,062	204
1945-1956	11.0	2,179	198
1956-1969	10.33	1,656	160
1969-1972	2.67	784	293
1972-1974	1.83	448	244
1974-1975	1.08	277	257
1975-1979	4.3	404	94
Predam Conditions			
1930-1956	26.0	5,241	202
Postdam Conditions			
1956-1979	20.21	3,569	177

Table 3-6

EROSION RATES WITH DISTANCE DOWNSTREAM FROM DAM GAVINS POINT DAM TO PONCA, NEBRASKA

1959-1975

Miles Below Dam	Erosion Rate (Acres/Mile/Year)
0-20	2.12
20-40	3.77
40-58	5.58

1975-1979

Miles Below Dam	Erosion Rate (Acres/Mile/Year)
0-19.4	2.22
19.4-40.4	7.17

f. **Discharge Records.** The flow duration curve for Gavins Point Dam is shown on plate 0-14. The mean daily discharge during the open-water season (April through October) have ranged from 6,000 c.f.s. to 63,400 c.f.s. Gavins Point Dam, which operates at steady state flows, has a mean discharge during the open-water season of 38,209 c.f.s. and a 50 percent flow for this period of about 35,800 c.f.s. The main stem reservoir system storage of the Missouri River reached above normal levels seven out of twelve years during the period 1969 to 1980; thus requiring above normal releases from Gavins Point Dam. The summer mean monthly discharge ranged from 28,000 c.f.s. to 62,000 c.f.s. and the winterdischarges ranged from 18,000 c.f.s. to 26,000 c.f.s.

g. **Slope.** The slope of the energy grade line averages approximately 1.0 feet per mile. Since the velocity head is usually small and the discharges uniform over a given time, the slopes of the water surface and the energy grade line are nearly equal. The slope varies with time, location, and river stage from approximately 0.6 feet per mile to 1.5 feet per mile as shown on plate 0-13.

2. TYPES OF RIVERBANK EROSION

Bank heights encountered at each demonstration site are presented in table 3-7. The types of erosion prevalent at these sites are discussed in the following paragraphs.

a. Mass wasting is a collective term which refers to several kinds of earth movement in which the primary moving force on regolith is gravity. In some mass wasting processes water plays an important part by saturating the regolith and making this downward movement easier. The saturation occurs in two ways: (1) rainfall penetrating the upper layers and percolating through the soils to create instability; and (2) undercutting which is the scaling of soil particles by seepage at the toe of a steep bank or bluff, ultimately creating a cantilever of overlying drier soil which fails by falling rather than sliding. Two classifications of mass wasting are found in the Gavins to Ponca reach of the Missouri. These are slump and debris flows.

(1) Slump is the downward slipping of a coherent body of regolith along a curved surface of rupture. The original surface of the slumped mass, and any flat-lying planes in it, become rotated as they slide downward. The movement creates a scarp facing downslope. On a river bank, slump is generally started when erosion by the river either steepened the bank or undercut it and made the bank material unstable.

(2) Debris flows, in some cases, begin with slump and develop a rapid downslope plastic flow. This type of flow often involves (but is not limited to) rapid movement under varying conditions. It commonly forms an apron-like or tongue-like area, with a very irregular surface. As the flow moves it develops concentric ridges and transverse furrows in the surface of the tongue-like portion.

b. Sloughing is the sliding or slipout of a thin mantle of earth, especially in a series of small movements. This is a slower form of erosion in which soluble and granular particles are removed as opposed to large chunks of bank material.

c. Shallow washing occurs when individual particles are washed away from the bank by fluctuating water levels and wave action.

d. Cutbank erosion occurs when a steep bare slope is created by lateral stream erosion. The lateral action of the water scours chunks of cohesive soil from the bank. These blocks of soil are washed into the river and then transported downstream.

Table 3-7

BANK HEIGHTS FOUND IN THE GAVINS POINT TO PONCA REACH

Project Site	Bank	Range	0-5'	6'-11'	11'-15'	15'
Cedar County Park	R	33B to 30.1			X	
(Phase I)	R	28.4		X		
	R	30 to 29.1			X	
	R	29 to 21Q		X		
	R	21P to 21M			X	
	R	21L to 21G		X		
	R	21D to 21			X	
Cedar County Park	R	20A to 13B			X	
(Phase II)	R	13 to 13A		X		
		15 to 16			X	
Goat Island	L	15B-1 to 12A-1		X		
	L	12A to 11A-1	X			
	L	11A to 9E-1		X		
	L	9E to 9C-1		X		
	L	9C	X			
	L	9B			X	
	L	9 to 3B-1		X		
	L	3B to 3-1			X	
	L	3 to 2A		X		
Vermillion Boat Club	L	1			X	
	L	2 to 5		X		
	L	6 to 10			X	
	L	12 to 23		X		
	L	25 to 33		X		
	L	34 to 46		X		
	L	47			X	
Brooky Bottom Road	R	1 to 4				X
	R	5 to 20			X	
	R	22 to 27		X		
	R	28 to 29			X	
	R	30 to 44				X
Mulberry Bend	R	17 to 22				X
	R	23 to 28			X	
	R	29 to 34		X		
Vermillion River Chute	L	1 to 21				X
	L	22 to 27			X	

Table 3-7 (Cont'd)

BANK HEIGHTS FOUND IN THE
GAVINS POINT TO PONCA REACH

Project Site	Bank	Range	0-5'	6'-11'	11'-15'	15'
Ryan Bend	R	18 to 1			X	
	R	2 to 7		X		
	R	8 to 13				X
Ionia Bend	R	1			X	
	R	1.1 to 1.2		X		
	R	2 to 2.1A				X
	R	2.2 to 3				X
	R	3.1 to 3.2		X		
	R	3.2A to 6				X
	R	6A to 11.2	X			
	R	11.2A to 12A		X		
Elk Point I and II	L	73 to 1				X

III - DESIGN AND CONSTRUCTION

A. GENERAL

In keeping with the Streambank Erosion Control Evaluation and Demonstration Act of 1974, the salient feature of each demonstration project was the control of streambank erosion by the employment of river management techniques using a variety of structural bank protection measures in combinations appropriate for local river conditions. Typical structural elements considered for each test reach were revetments, vane dikes, and artificial hardpoints, each discussed in detail in Section III-B. The general design considerations investigated for each demonstration site are delineated below. The critical technical factors affecting the structural design and stability included bedscour at the toe of the bank, weathering in the zone of stage variation, and ice action. Because of the control imposed by

Gavins Point Dam in this reach, it was unlikely that design stages would not likely be exceeded or protection works damaged by frequent overtopping. The river stages experienced remained below the top of existing high banks and varied between well defined limits.

1. FIELD CONDITIONS. Field conditions are physical conditions which must be delineated and evaluated to permit development of structural designs that are equally functional, constructable, and environmentally acceptable. The following field conditions were considered at each site:

- Channel location and alignment (main and secondary)
- Channel geometry (cross-section)
- Bar/island formation (location orientation, elevation, material)
- Near-bank flow conditions (depth, velocity)
- Bank heights, configuration, materials
- High bank land use
- Riverbed and bank material types and conditions
- Stage-duration relationships (average daily and long-term probability)
- Tributary streams and surface runoff locations
- Groundwater seepage
- Potential wave erosion
- Existing erosion controls (natural, manmade)
- Degradation projections

2. CONSTRUCTIBILITY FACTORS. Constructibility factors are those practical factors relative to actual construction materials, operations, and techniques which must be considered to assure optimum project economics and to minimize potential environmental impacts.

a. Material sources (stone, cobbles, gravel)
   - Quality
   - Quantity available
   - Location from project (haul distance)
   - Cost, at source (royalties, quarrying, gathering)

b. Land access to structural locations

- Haul road location and conditions
- Near-bank conditions (height, soils, vegetation)
- Mobilization and materials handling sites

c. River Access (floating plant construction)

- River depths along project bankline
- Near-bank conditions
- Mobilization and material handling sites
- River depths, distance, and alignment from project site to potential mobilization and material handling sites

3. **ENGINEERING OBJECTIVES.** Engineering objectives are those goals established to provide perspective and scope to individual project formulation and design.

- Least-cost, multipurpose problem solutions
- Materials
- Construction techniques
- Structure type, location, and orientation
- Minimize potential future maintenance costs

4. **ENVIRONMENTAL OBJECTIVES.** These are environmental considerations taken into account in the formulation and general design of individual projects.

- Minimize woodland clearing or the disturbance of any other sensitive or unique habitat
- Protect important or critical habitat
- Avoid disturbance of endangered fish and wildlife species during construction
- Create desirable aquatic habitat with structure configuration or various types of structure materials

- Consider structure designs that improve pedestrian and wildlife access to the water's edge

- Preserve the natural appearance and aesthetics of the waterway; conceal structures with topsoil and native vegetation; low profile structures generally less noticeable.

- Avoid destruction of or protect cultural resources as appropriate

B. BASIC DESIGN FOR EACH TYPE OF PROTECTION.

Typical bank protection schemes considered for demonstration sites in the Gavins Point to Ponca reach of the Missouri River are shown on plates 0-15 through 0-17 and discussed in the following paragraphs.

The range of stone application rates along with the average tons per linear foot by structure type for the Gavins Point to Ponca reach are shown in table 3-8.

Table 3-8
APPLICATION RANGE AND APPLICATION RATE
OF TYPICAL STRUCTURE TYPES

Structure Type	Application Range (Tons/Linear Foot)	Average Application Rate (Tons/Linear Foot)
Reinforced Revetment	4.2 - 5.7	5.5
Composite Revetment	4.3 - 5.6	4.8
Windrow Revetment	3.6 - 5.5	4.7
Windrow Refusal	4.0 - 6.2	5.1
Hardpoints	5.6 - 6.8	6.0

1. **REVETMENT.** Revetments consist of a facing of stone or other material placed adjacent and parallel to the bankline to protect against erosion. These structures are generally utilized where river flows are concentrated

along the bank and where depths, bankline configuration or bankline conditions preclude the use of other methods.

Typical demonstration structure layouts intentionally leave 200 to 1,000 feet of unprotected bank between structure segments. The extent of interstructure erosion is limited by the prevailing water depth and velocity riverward of the structure alignment (the theoretical line connecting the riverward extremity of all the structures in the system); the bank height and composition; and the structure spacing. As the river erodes into the bank, the flow path becomes larger since the water entering the erosion "bight" must return to the original bank location at the next downstream structure. Accordingly, the energy gradient becomes proportionally less as the size of the bight grows. Thus, at a given river stage (discharge) the bight ceases to grow when the velocity and eddy is no longer sufficient to remove material from the bank. The resulting configuration and cross section of the "stable" bank will remain stable as long as extended duration flows do not exceed the flow level which created that configuration.

Revetments in this river reach have three distinct zones in which stresses differ and accordingly the material requirements can be varied. The toe zone is that portion of the structure below normal low-water, subject only to river current erosion. Material in this zone must be of sufficient size and quality to resist the erosive force of the river velocities continually flowing adjacent to it; and it must be of sufficient gradation and quantity to form a reasonably dense blanket over the slope, down to the depth of anticipated maximum scour. This material is seldom exposed to freeze-thaw or wet-dry action, or ice and debris movement. Accordingly, material of relatively inferior mechanical properties (weak, brittle, soft, etc.) should function adequately in this zone, if of sufficient size to resist movement by the flow.

The splash zone is that portion between the normal high-water and normal low-water. This is the zone of highest stress. The material is frequently exposed to wet-dry and freeze-thaw cycles, ice and debris movement, wave-wash, and erosive river currents. These stresses will generally require high quality stone; however, some combination of gravel, clay, filter cloth, etc., may be functional here.

The bank zone is that portion above normal high-water. Material in this zone is continually exposed to weathering, and periodically exposed to high stage erosion, wave-wash, ice and debris, and traffic by animals or man. It appears that a tough vegetation cover on a graded bank would be an optimum solution. However, types of vegetation and the minimum degree of grading to provide a durable, low-maintenance solution need development. In some cases, a stronger treatment may be necessary such as gravel, clay, soil cement, etc. General revetment applications include variations of three basic designs, as field conditions, environmental, and cultural considerations dictate.

a. **Windrow Revetment.** The Windrow Revetment structure, shown on Plate 0-17, consists of a mound of stone placed on the ground, or partially or totally buried, immediately adjacent and parallel to the general alignment of the eroding bank. In theory, a minimum windrow is placed first and then as the bank erodes the stone is undercut and sloughs down the bankline and blankets the new bank at a naturally established slope. Then stone material is added on an as-needed basis until equilibrium (i.e., a stable bank) is established. This provides a structure containing the least possible amount of stone, and accordingly, the least cost for a revetment-type structure. Variable factors that require evaluation include stone gradation, mound size and shape, minimum initial application rate, size and shape of the excavated trench, structural segment lengths and spacing, and an estimate of the ultimate depth of scour. The Windrow Revetment is an excellent technique in areas where river flows are unusually deep and swift along the toe of the bankline. This technique avoids the excessive quantity

of material needed to construct a fill within the water area in such situations. However, the presence of improvements or heavy timber usually necessitates substitution of alternative techniques in areas otherwise suited to windrow revetment.

b. Composite Revetment. The Composite Revetment structure technique, shown on plate O-15, is used where flows are concentrated along the bankline, but where depths or curvature preclude hardpoint systems and bankline or environmental conditions preclude windrow revetment. Composite revetment consists of a toe of erosion-resistant material, a splash zone treatment covering the area of normal seasonal fluctuations, and a freeboard zone that is generally vegetated. Toe crown elevations are normally placed at the estimated low water elevations to reduce exposure to free-thaw and wet-dry cycles and thus permit the use of relatively low quality erosion-resistant material in the toe. Toe material is generally placed on the natural riverbed; however, minor excavation is accomplished whenever necessary to provide an adequate structural section. The upper bank treatment generally includes erosion resistant material placed in the configuration to best satisfy aesthetic, environmental, and economic criteria.

c. Reinforced Revetment. The Reinforced Revetment, shown on plate O-16 consists of a toe of erosion-resistant material placed somewhat riverward of the bankline. The toe is then reinforced by intermittent stone-filled tiebacks, which are placed on the riverbank or in an excavated trench and extend landward from the toe to or into the riverbank. The toe fill material may either be high quality stone, low grade material, or both. The fill material used in the tieback is generally stone. The toe material is placed on the riverbed generally parallel to the natural bankline. The toe fill crown is generally constructed to the normal water surface elevation but may be lower. The stone tiebacks slope upward from crown of the toe fill to several feet above the normal water surface elevation at the existing bankline. Between tiebacks, the upper bank may be graded to fill voids between

tiebacks, the bank, and the toe. The upper bank surfaces of reinforced revetment may be covered with either gravel or topsoil and seeded to satisfy aesthetic and environmental considerations.

2. **HARDPOINTS.** The hardpoint structure consists of two components: a short spur 30 to 50 feet long of erosion-resistant material extending from the bank into the river; and a root of erosion-resistant material 30 to 50 feet long placed in a trench excavated landward from the bankline. Hardpoint systems are used when possible in lieu of revetment systems as a more economical measure and also to develop diversity in the aquatic and near-bank-environment. They are best utilized along relatively long, convex-shaped or straight bankline increments having water depths of 5 to 10 feet. The upstreammost hardpoint in multi-hardpoint systems may be longer and of heavier section than the "shaded" downstream hardpoints. The crown width of the spur varies up to 10 feet maximum and is generally inversely proportional to water depth. This width may also reflect maintenance and access considerations. The crown elevation is generally at the normal water surface at the riverward end, and slopes up to varying elevations at the bankline, depending on bank height and root type. There are two basic root types: a deep "V" excavation for high banks and a wide, shallow trench for low banks. Spurs are angled 10°-20° downstream of the normal to the bankline and are designed to provide an adequate amount of material to withstand anticipated scour conditions.

3. **VANE DIKES.** On rivers with the characteristics of the reach from Gavins Point to Ponca, where erosion control, aesthetic value, and environmental consideration are paramount, the vane dike structure system should be considered. Vane dikes are a technique for causing deterioration of active chutes carrying too much flow for possible chute closure consideration. The system consists of multiple dikes constructed askew to the direction of channel flow and not connected to the bank. The purpose of the vane dike is to direct the main channel flow away from the erosion area, provide small side channels of slower

moving water, and induce artificial sandbars and marsh areas on the land side of the structures. These changes influence the channel to return to a more natural, less damaging alignment. Constructed of riprap, the vane dikes assure long-term presence of the bar and thus greatly reduce erosion in the bight. Designs should utilize variable flow levels to promote predetermined degrees and extent of vegetational succession on the bar. Since vane dikes are constructed by floating plant, this erosion control technique is invaluable if it is necessary to avoid any on-bank construction because of legal, environmental, or acheological factors.

4. **WINDROW REFUSAL.** A windrow refusal, shown on plate 1-3, is always constructed at the upstream end of each revetment segment to prevent flanking of the revetment as the interstructure bight develops and flow concentrations return to the original bank location. Each refusal generally consists of erosion-resistant material placed in a 30-100 foot trench excavated landward from the bankline. Refusals are usually angled 10°-20° downstream of the normal to the bankline, depending upon local bankline conditions.

5. **SPECIAL CONSTRUCTION PROVISIONS.** Bidding schedules developed for the plans and specifications advertised for each demonstration project contained options for allowing the bidder to utilize low grade material in all structures specified on the construction schedule as "Stone or Low Grade Material" or to utilize all high quality stone in these structures. The low bid for utilization of stone and low grade material was accepted unless the low bid for utilization of all stone did not exceed the stone and low grade material low bid by a predetermined percentage. This percentage was based on District bid experience for similar contracts and an engineering determination of the premium worth of construction utilizing high quality materials exclusively, and varied from contract to contract.

Stone, as specified for the contracts in this reach, was defined as durable material meeting specified acceptability levels based on service records and laboratory tests, such as petrographic analysis, specific gravity, absorption, wetting and drying, soundness in magnesium sulfate, and freezing and thawing. Gradations were determined by field conditions or experimental considerations. Neither the breadth nor the thickness of any piece of stone shall be less than one-third of its length. Stone shall be reasonably well-graded from coarse to fine. Dirt and fines of less than 1/2-inch maximum cross-section, accumulated from interledge layers or from blasting or handling operations shall not exceed 5 percent by weight.

Low grade materials, such as softer sandstones, limestone or chalk, were suitable for utilization to provide the bulk necessary in the toe of revetments and the core of hardpoints, provided laboratory testing, field tests, and service records demonstrated minimum acceptability within the specifications. It was specified only by minimum specific gravity, a maximum allowable absorption and loss after a reasonable period of immersion, a liberal gradation range, and a requirement that it be obtained from the source and placed in the structure without excessive deterioration or mechanical breakdown.

Acceptance testing of field boulders for compliance with quality requirements was not required. Gravels, cobbles and spalls used to provide an upper bank treatment are specified as tough, durable particles reasonably free from flat, thin and elongated pieces, and containing no objectionable quantities of soft, friable materials or organic matter. Gradation limits may be liberal to promote trial of locally available material and possibly material from the channel bed in the vicinity of the structures utilizing gravel. Gradations specified at each demonstration site in this reach are discussed in Section C.

Normal Water Surface (NWS), as defined for the demonstration projects throughout this reach, is a plane of elevation reference for the

various types of construction required by the project specifications. In construction usage, the NWS plane provides a sloping line of "normal" water elevations along the river from the vicinity of Gavins Point Dam to Ponca, Nebraska. The relationship between NWS and each type of construction is shown on the appropriate typical section drawings for each project location. The NWS profile for this river reach is shown on plate 0-13.

C. CONSTRUCTION DETAILS AT EACH DEMONSTRATION PROJECT

1. **CEDAR COUNTY PARK PHASE I PROJECT AREA.** The general plan for this project is shown on plate 1-1. The demonstration area consists of two reinforced revetment segments totaling 1,350 linear feet, four segments of composite revetment totalling 2,300 linear feet, one system of hardpoints consisting of 3 structures, seven windrow refusal structures totalling 400 linear feet, and one segment of windrow revetment totalling 800 feet. Typical sections of the structure types used in this project are shown on plates 1-2 and 1-3. All segments of composite revetment constructed are Case I. Reinforced Revetment 799.64 is Type II, with a tieback interval of 100 feet. Reinforced Revetment 798.50 is Type I, with a tieback interval of 200 feet. A tieback was constructed at the downstream end of each reinforced revetment structure to reduce the possibility of back eddy damage to the structure toe. All hardpoint roots are Type A, as shown in plate 1-3, with root elevations 2 feet below the existing ground elevation at the landward end of the roots. The windrow revetment is Type A. No mandatory floating plant construction was required in this contract.

Table 3-11 provides a construction program which includes material quantities and costs by structure. Low grade material did display sufficient economic advantage as a bid item for this contract.

Tables 3-9 and 3-10 display the specified gradation requirements for the small and large stone material utilized in the structures.

The stone material was required to meet the following standards: bulk specific gravity, saturated surface-dry basis Method CRD-C 107-69, required not less than 2.35. Soundness in magnesium sulfate, ASTM Standard C88-76, required a loss at 5 cycles of not more than 12 percent. Soundness in freezing and thawing for ledge rock, Method Modified Designation T 103-62, required a loss at 12 cycles not to exceed 10 percent.

Table 3-9

STONE GRADATION FOR COMPOSITE REVETMENT TOE (UPPER), REINFORCED REVETMENT TIEBACKS, WINDROW REVETMENT AND REFUSALS, HARDPOINT UPPER PAVING FILL AND ROOT

Weight Per Piece	Percent of Total Weight Lighter than or Passing
200-lbs	100
50-lbs	35-60
2-inch screen	0-15

Table 3-10

STONE GRADATION FOR COMPOSITE REVETMENT TOE (LOWER), REINFORCED REVETMENT TOE, AND HARDPOINT CORE

Weight Per Piece	Percent of Total Weight Lighter than or Passing
500-lbs	100
165-lbs	35-60
3-inch screen	0-15

Stone application rates in average tons per linear foot by structure type for this project site are as follows.

Reinforced Revetment	4.8
Composite Revetment	4.8
Windrow Revetment	4.5
Windrow Refusal	6.1
Hardpoints	6.5

Typical bankline erosion at the Cedar County Park (Phase I) Area is shown on photo 1. Photographs 2 and 3 show examples of Reinforced Revetment Types I and II. Photos 4 through 7 show the construction sequence for a Windrow Revetment Type A. Photograph 8 shows a typical Composite Revetment. Photos 9 and 10 show a hardpoint structure during and after construction.

Table 3-11

CEDAR COUNTY PARK - PHASE I CONSTRUCTION PROGRAM

Struc. No.	Type**	Length (ft)	Date Start	Date Finish	Stone (Tons)	L.G.M. (Tons)	Gravel (Tons)	Excav. (CY)	Cost ($)	$/L.F.
799.65*	WRF	100	8/01/79	8/02/79	600			570	10,050.00	100.50
799.64	RR	650	8/13/79	9/14/79	525	2,840	496	2,038	55,411.50	85.25
799.44*	WRF	50	7/31/79	7/31/79	304			285	5,080.60	101.61
799.43*	WR	800	7/23/79	9/06/79	3,600			4,547	53,451.00	66.81
799.27*	HP	70	9/24/79	9/24/79	235	202	25	180	6,647.35	94.96
799.23*	HP	60	9/25/79	9/25/79	210	194	20	180	6,130.20	102.17
799.20*	HP	70	9/26/79	9/26/79	235	231	25	180	7,004.05	100.06
799.16*	WRF	50	7/30/79	7/30/79	303			285	5,066.70	101.33
799.15										
s&a 0+00										
+0										
4+00	CR	400			780	1,029	240		26,918.70	67.00
6+50										
to										
12+50	CR	600			1,140	1,510	382		39,962.50	66.00
14+50										
to										
19+50	CR	500			1,000	1,578	300		37,584.40	75.00
22+50										
to										
30+50	CR	[illegible]			1,600	2,359	480		58.095.70	73.00
798.95*	WRF	50	7/28/79	7/28/79	306			285	5,108.40	102.17
798.85*	WRF	50	7/27/79	7/27/79	305			285	5,094.50	101.89
798.78*	WRF	50	7/28/79	7/28/79	305			285	5,094.50	101.89
798.51*	WRF	50	7/28/79	7/28/79	304			285	5,080.60	101.61
798.50*	RR	700	8/29/79	9/11/79	330	2,821	420	497	46,761.30	66.80

SUBTOTAL	$378,000.00
Clearing and Grubbing	19,000.00
Seeding	4,000.00
Monitoring	46,000.00
Supervision and Administration	26,000.00
Engineering and Design	25,000.00
TOTAL COST	$498,000.00

*Designated by 1960 River Mileage

**WRF = Windrow Refusal; RR = Reinforced Revetment;
HP = Hardpoint; WR - Windrow Revetment

PHOTO 1. TYPICAL BANKLINE EROSION AT CEDAR COUNTY PARK AREA
(Photo Taken 5 October 1979)

PHOTO 2. REINFORCED REVETMENT 799.64*, TYPE II, LOOKING D/S, APPROXIMATELY 3 WEEKS AFTER STRUCTURE COMPLETION
(Photo Taken 5 October 1979)

CEDAR COUNTY PARK I AREA
Photos 1 and 2

PHOTO 3. REINFORCED REVETMENT 798.50*, TYPE I, LOOKING U/S THE STRUCTURE WAS CONSTRUCTED WITH A LOW GRADE MATERIAL (CHALK) TOE COVERED BY A THIN LAYER OF GRAVEL. THE CHALK NEAR WATER SURFACE IS BREAKING DOWN CONSIDERABLY
(Photo Taken 19 March 1981)

PHOTO 4. SITE OF WINDROW REVETMENT 799.43*, TYPE A, LOOKING U/S, PRIOR TO CONSTRUCTION SHOWING THE SEVERE EROSION ALONG THIS AREA
(Photo Taken 16 April 1979)

PHOTO 5. WINDROW REVETMENT 799.43*, TYPE A, LOOKING U/S AFTER EXCAVATION
(Photo Taken 23 July 1979)

PHOTO 6. WINDROW REVETMENT 799.43*, TYPE A, PHOTO SHOWS STAGE OF CONSTRUCTION 6 DAYS PRIOR TO COMPLETION OF THE ENTIRE SEGMENT
(Photo Taken 25 July 1979)

PHOTO 7. WINDROW REVETMENT 799.43*, TYPE A, LOOKING U/S AFTER COMPLETION
(Photo Taken 24 September 1979)

PHOTO 8. COMPOSITE REVETMENT 799.15*, STATION 10+00 TOE WAS CONSTRUCTED OF LOW GRADE MATERIAL WITH STONE AND GRAVEL COVER. PHOTO SHOWS STRUCTURE APPROXIMATELY 1 YEAR and 6 MONTHS AFTER COMPLETION
(Photo Taken 19 March 1981)

PHOTO 9. HARDPOINT 799.20* DURING CONSTRUCTION. THE STRUCTURE IS COMPOSED OF LOW GRADE MATERIAL UP TO NWS AND THEN CAPPED WITH STONE AND GRAVEL
(Photo Taken 21 September 1979)

PHOTO 10. HARDPOINT 799.27*, AFTER COMPLETION. THE STRUCTURE IS COMPOSED OF LOW GRADE MATERIAL UP TO NWS, CAPPED WITH STONE AND THEN COVERED WITH A 6-INCH LAYER OF GRAVEL
(Photo Taken 5 October 1979)

2. **CEDAR COUNTY PARK (PHASE II) PROJECT AREA**. The general plan for this project is shown on plate 2-1. The demonstration area encompasses the remaining portion of the Cedar County Park Area not protected by the Cedar County Park (Phase I) Project, described in detail in Section III C-1 of this appendix. Construction consisted of two segments of reinforced revetment totalling 1,200 linear feet, two windrow refusals totalling 125 linear feet, and one system of hardpoints consisting of 7 structures. Plates 2-2 through 2-4 show typical sections of structures used in this contract. There is a 700-foot segment of reinforced revetment-Type II and a 500-foot segment of reinforced revetment-Type IV. Both segments of reinforced revetment have tieback intervals at 200 feet with a tieback constructed at the downstream end of each segment. The seven hardpoints all have Type A stone roots extending landward into the bank, with root elevations 2 feet below existing ground elevation at the landward end of the root. The hardpoint spur elevation is the Normal Water Surface elevation plus 3.0 feet. The crown width on each hardpoint spur is 5.0 feet.

Table 3-14 provides a construction program which includes material quantities and costs by structure. Low grade material did display sufficient economic advantage as a bid item for this contract.

Tables 3-12 and 3-13 display the specified stone gradations.

Table 3-12

STONE FOR COMPOSITE REVETMENT TOE (UPPER), REINFORCED REVETMENT TIEBACKS, WINDROW REFUSALS, HARDPOINT UPPER PAVING FILL AND ROOT

Weight or Size Per Stone	Percent of Total Weight Lighter than or Passing
200-lbs	100
50-lbs	35-60
2-inch screen	0-15

Table 3-13

STONE FOR COMPOSITE REVETMENT TOE (LOWER), REINFORCED REVETMENT TOE, AND HARDPOINT CORE

Weight or Size Per Stone	Percent of Total Weight Lighter than or Passing
500-lbs	100
165-lbs	35-60
3-inch screen	0-15

The stone material was required to meet the following standards: Bulk specific gravity, saturated surface-dry basis Method CRD-C 107-69, required not less than 2.40. Soundness in magnesium sulfate, ASTM Standard C88-76, required a loss at five cycles of not more than 12 percent. Soundness in freezing and thawing for ledge rock, Method Modified Designation T 103-62, required a loss at 12 cycles of not more than 10 percent.

Stone application rates in average tons per linear foot by structure type for this project site are as follows.

Reinforced Revetment	5.2
Windrow Refusal	6.0
Hardpoints	6.6

Photos 11 and 12 show a hardpoint and reinforced revetment Type IV after completion in the Cedar County Park II contract area.

Table 3-14

CEDAR COUNTY PARK - PHASE II CONSTRUCTION PROGRAM

Struc. No.	Type**	Length (ft.)	Date Start	Date Finish	Stone (Tons)	L.G.M. (Tons)	Gravel (Tons)	Excav. (CY)	Cost ($)	$/L.F.
798.50										
10+00 to 17+00	RR	700	6/03/80	6/26/80	311	3,343	420	3,119	63,656.60	91.00
20+00 to 25+00	RR	500	6/03/80	6/26/80	225	2,340	300	2,259	44,982.00	90.00
798.37*	WRF	75	5/22/80	5/22/80	450			357	7,641.00	101.88
798.11*	WRF	50	5/27/80	5/27/80	300			285	5,235.00	104.70
797.96*	HP	100	5/27/80	6/12/80	350	265	30	346	10,043.00	100.43
797.92*	HP	100	5/28/80	6/13/80	350	262	30	325	9,941.00	99.41
797.88*	HP	80	5/28/80	6/16/80	260	260	30	209	8,253.00	103.16
797.84*	HP	90	5/28/80	6/17/80	305	258	30	262	9,043.00	100.48
797.78*	HP	90	5/27/80	6/18/80	305	261	30	249	9,043.00	100.48
797.74*	HP	90	5/29/80	6/19/80	305	263	30	88	8,586.00	95.40
797.70*	HP	80	5/29/80	6/28/80b	160	261	30	196	8,227.00	102.84

SUBTOTAL	$185,000.00
Clearing & Grubbing & Seeding	15,000.00
	2,000.00
Monitoring	23,000.00
Supervision and Administration	10,000.00
Engineering and Design	5,000.00
TOTAL COST	$240,000.00

*Designated by 1960 River Mileage

**WRP = Windrow Refusal, RR = Reinforced Revetment;
HP = Hardpoint

PHOTO 11. HARDPOINT 797.84*, LOOKING D/S
APPROXIMATELY 9 MONTHS AFTER STRUCTURE COMPLETION
(Photo Taken 19 March 1981)

PHOTO 12. COMPLETED REINFORCED REVETMENT 798.50*, TYPE IV
CONSTRUCTED OF A LOW GRADE MATERIAL TOE WITH 6-INCH
GRAVEL COVER, AND STONE TIEBACKS
(Photo Taken 19 March 1981)

3. **GOAT ISLAND PROJECT AREA.** The general plan for this project is shown on plate 3-1. The demonstration area consists of 8 segments of reinforced revetment totalling 4,400 linear feet, 5 segments of composite revetment totalling 3,000 linear feet, one system of hardpoints consisting of 5 structures, 16 windrow refusals totalling 1,150 linear feet, and 3 segments of windrow revetment totalling 1,700 linear feet. Typical sections of the structure types used in this project are shown on plates 3-2 and 3-3. All segments of composite revetment constructed are Case II, requiring excavation. The composite revetment structures are 600 feet long with 300-foot gaps between segments. Reinforced Revetment 797.62 is a Type I at stations 0+00 to 6+00 and 9+00 to 15+00. The tieback interval at station 0+00 to 6+00 is 100 feet whereas the tieback interval at station 9+00 to 15+00 is 80 feet. Reinforced Revetment 797.62, station 18+00 to 21+00 and Reinforced Revetment 796.9, station 0+00 to 3+00, are both Type II with a tieback interval of 50 feet. A tieback interval of 100 feet was used for Reinforced Revetment Type II 796.9, station 5+00 to 17+00. Reinforced Revetment 796.2 was constructed in 3 segments of 600 feet, 400 feet, and 400 feet, respectively. Each segment is a Type III; however, the tieback intervals were varied with each segment. The tieback interval at station 0+00 to 6+00 is 100 feet; the tieback interval at station 9+00 to 13+00 is 50 feet; and the tieback interval at station 14+80 to 18+80 is 80 feet. The tieback intervals for these structures were varied for demonstration purposes. On all reinforced revetment segments a tieback was constructed at the downstream end of each structure to reduce the possibility of back eddy damage to the structure toe.

The hardpoint roots farthest upstream in the structure system are Type B for low bank conditions, as shown on plate 3-3. The three hardpoint roots farthest downstream are Type A, also shown on plate 3-3. All root elevations are 2 feet below existing ground elevation at the landward end of the roots. No mandatory floating plant construction was required for this contract.

Table 3-17 provides a construction program which includes material quantities and costs by structure. Low grade material did not display sufficient economic advantage as a bid item for this contract; therefore, all structures in this project were constructed of durable stone. Tables 3-15 and 3-16 display the specified gradation requirements for the small and large stone material utilized in the structures. Bulk specific gravity, saturated surface-dry basis Method CRD-C 107-69, required not less than 2.40 soundness in magnesium suulfate, ASTM Standard C88-76, required a loss of 5 cycles of not more than 12 percent. Soundness in freezing and thawing for ledge rock, Method Modified Designation T 103-62, required a loss at 12 cycles not to exceed more than 10 percent.

Table 3-15

STONE GRADATION FOR COMPOSITE REVETMENT TOE (UPPER), REINFORCED REVETMENT TIEBACKS, WINDROW REVETMENT AND REFUSAL, HARDPOINT UPPER PAVING FILL AND ROOT

Weight or Size per Stone	Percent of Total Weight Lighter than or Passing
200-lbs	100
50-lbs	35-60
2-inch screen	0-15

Table 3-16

STONE GRADATION FOR COMPOSITE REVETMENT TOE (LOWER), REINFORCED REVETMENT TOE, AND HARDPOINT CORE

Weight or Size per Stone	Percent of Total Weight Lighter than or Passing
500-lbs	100
165-lbs	35-60
3-inch screen	0-15

Stone application rates in average tons per linear foot by structure type for this project site are as follows.

Reinforced Revetment	5.5
Composite Revetment	5.0
Windrow Revetment	4.8
Windrow Refusal	6.1
Hardpoints	6.0

Photos 13 and 14 show 200-lb and 500-lb gradation tests. Photos 15 through 18 show a typical windrow revetment and reinforced revetment. Photos 19 through 21 portray the construction sequence for Reinforced Revetment 796.9. Photos 22 through 24 show composite revetment structures during and after construction. Photos 25 and 26 show not only a completed hardpoint, but also a hardpoint system demonstrating the spacing interval and existing bank conditions.

Table 3-17

GOAT ISLAND CONSTRUCTION PROGRAM

Struc. No.	Type**	Length (ft.)	Date Start	Date Finish	Stone (Tons)	Gravel (Tons)	Excav. (CY)	Cost ($)	$/L.F.
797.63*	WRF	75	8/17/78	8/18/78	442		353	7,070.65	94.28
797.62	RR	1,500	8/17/78	9/9/78	7,745	809	6,328	132,307.00	88.00
Sta. 0+00									
to									
6+00									
9+00									
to									
15+00									
18+65									
to									
21+65									
797.51*	WRF	75	8/16/78	8/17/78	443		376	7,136.00	95.15
797.36*	WRF	75	8/14/78	8/16/78	448		545	7,587.85	101.17
797.21*	WRF	75	8/10/78	8/11/78	459		358	7,323.30	97.64
797.20*	WR	700	8/11/78	8/30/78	1,962		3,096	34,826.40	49.75
796.92*	WRF	75	9/10/78	9/11/78	421		350	6,765.70	90.21
796.9									
0+00	RR	300	10/13/78	10/20/78	1,716	189	676	27,778.20	93.00
to									
3+00									
5+00	RR	1,200	10/13/78	10/20/78	5,996	881	2,337	99,211.45	83.00
to									
17+00									
796.85*	WRF	75	9/20/78	9/21/78	424		382	6,880.30	91.74
796.70*	HP	100	9/15/78	9/16/78	511	14	275	8,014.95	80.15
796.65*	HP	100	9/18/78	9/19/78	481	14	293	7,629.45	76.29
796.60*	HP	100	9/19/78	9/20/78	663	14	219	10,047.35	100.47
796.55*	HP	100	9/20/78	9/21/78	696	14	220	10,518.20	105.28
796.50*	HP	100	9/21/78	9/22/78	671	14	220	10,163.20	101.63
796.46*	WRF	75	8/31/78	9/01/78	451		350	7,191.70	95.89
796.45									
0+00	WR	400	9/01/78	10/04/78	2,492		1,877	39,609.65	99.00
to									
4+00									
7+45	WR	600	9/01/78	10/04/78	3,640		2,815	58,021.75	97.00
796.35*	WRF	75	10/06/78	10/06/78	481		547	8,060.95	107.48

Table 3-17 (Cont'd)

GOAT ISLAND CONSTRUCTION PROGRAM

Struc. No.	Type**	Length (ft.)	Date Start	Date Finish	Stone (Tons)	Gravel (Tons)	Excav. (CY)	Cost ($)	$/L.F.
796.21*	WRF	75	9/28/78	9/28/78	449		335	7,174.55	95.66
796.2									
0+00 to 6+00	RR	600	10/03/78	10/31/78	3,559	268	2,186	58,136.30	97.00
9+00 to 13+00	RR	400	10/03/78	10/31/78	2,665	175	1,458	42,873.50	107.00
14+80	RR	400	10/03/78	10/31/78	2,377	173	1,457	38,761.65	97.00
795.99*	WRF	50	10/11/78	10/12/78	312		234	4,956.90	99.14
795.90*	WRF	50	10/12/78	10/12/78	298		231	4,751.35	95.03
795.81*	WRF	75	10/16/78	10/17/78	457		389	7,364.65	98.20
795.8									
0+00 6+00	CR	600	10/13/78	11/30/78	1,973	234	665	31,852.85	53.00
9+00 to 15+00	CR	600	10/13/78	11/30/78	3,044	238	665	47,101.05	79.00
18+00 to 24+00	CR	600	10/13/78	11/30/78	4,033	199	665	60,754.85	101.00
27+00 to 33+00	CR	600	10/13/78	11/30/78	3,067	200	665	47,047.65	78.00
36+00 to 42+00	CR	600	10/13/78	11/30/78	2,937	244	666	45,643.90	76.00
795.70*	WRF	75	10/24/78	10/24/78	455		350	7,248.50	96.65
795.60*	WRF	75	10/24/78	10/24/78	416		394	6,793.70	90.58
795.50*	WRF	75	10/25/78	10/26/78	506		324	7,914.20	105.52
795.40*	WRF	75	10/26/78	10/27/78	506		383	8,046.95	107.29

SUBTOTAL	$ 923,000.00
Clearing and Grubbing	23,000.00
Seeding	4,000.00
Monitoring	27,000.00
Engineering and Design	53,000.00
Supervision and Administration	55,000.00
TOTAL COST	$1,085,000.00

*Designated by 1960 River Mileage

**WRF - Windrow Refusal; RR + Reinforced Revetment;

HP = Hardpoint; CR = Composite Revetment;

WR = Windrow Revetment

PHOTO 13. 200 LB. GRADATION TEST
(Photo Taken 8 August 1978)

PHOTO 14. 500 LB. GRADATION TEST
(Photo Taken 26 September 1978)

GOAT ISLAND AREA
Photos 13 and 14

PHOTO 15. SITE OF WINDROW REVETMENT 797.2* PRIOR TO CONSTRUCTION, LOOKING D/S
(Photo Taken 8 August 1978)

PHOTO 16. EXCAVATION FOR WINDROW REVETMENT 797.2*, LOOKING D/S
(Photo Taken 14 August 1978)

<u>GOAT ISLAND AREA</u>
Photos 15 and 16

PHOTO 17. COMPLETED WINDROW REVETMENT 797.2*, LOOKING D/S FOR THE WINDROW REVETMENT TO FUNCTION, THE RIVERBANK MUST ERODE ANOTHER 3 - 5 FEET
(Photo Taken 28 June 1979)

PHOTO 18. REINFORCED REVETMENT 796.45* APPROXIMATELY ONE YEAR AFTER COMPLETION. THIS PHOTO, LOOKING U/S, PROVIDES A VISUAL COMPARISON OF THE ORIGINAL SEVERELY ERODING UNPROTECTED BANK CONDITION AND ITS PRESENTLY STABILIZED CONDITION
(Photo Taken 5 October 1979)

PHOTO 19. SITE OF REINFORCED REVETMENT 796.9* PRIOR TO CONSTRUCTION, LOOKING D/S
(Photo Taken 22 August 1978)

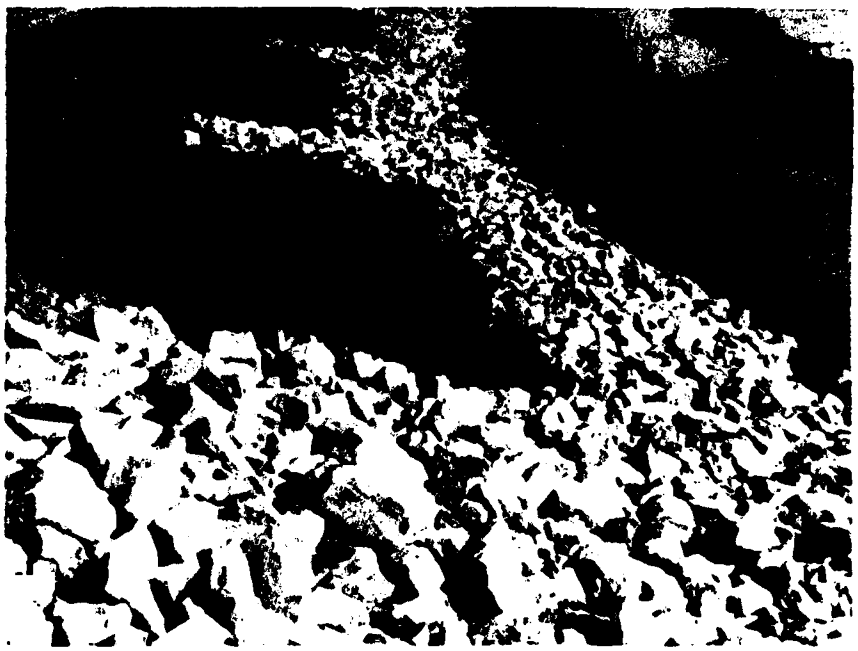


PHOTO 20. REINFORCED REVETMENT 796.9* AFTER STONE PLACEMENT BUT PRIOR TO GRAVEL COVER LOOKING D/S
(Photo Taken 18 September 1978)

GOAT ISLAND AREA
Photos 19 and 20

PHOTO 21. REINFORCED REVETMENT 796.9* NINE MONTHS AFTER COMPLETION. STRUCTURE SHOWS SUBSTANTIAL VEGETATIVE COVER WHICH GREATLY ENHANCES THE AESTHETIC QUALITIES OF THE SITE
(Photo Taken 28 June 1979)

PHOTO 22. COMPOSITE REVETMENT 795.6*, LOOKING W/S, ONE YEAR AFTER COMPLETION. NOTE THE MINIMAL AMOUNT OF UPPER BANK DISTURBANCE AND THE DENSE VEGETATION GROWTH
(Photo Taken 5 October 1979)

PHOTO 23. COMPOSITE REVETMENT 795.81*, LOOKING D/S. PHOTO SHOWS METHOD OF STONE TOE PLACEMENT BY LAND-BASE CONSTRUCTION TECHNIQUES. (Photo Taken 16 October 1979)

PHOTO 24. COMPOSITE REVETMENT 795.81*, LOOKING U/S, APPROXIMATELY ONE YEAR AFTER STRUCTURE COMPLETION (Photo Taken 5 October 1979)

PHOTO 25. COMPLETED HARDPOINT 796.6*
(Photo Taken 13 April 1979)

PHOTO 26. COMPLETED HARDPOINT SYSTEM DEMONSTRATING SPACING INTERVAL AND EXISTING BANK CONDITIONS
(Photo Taken 13 April 1979)

4. **VERMILLION BOAT CLUB**. The general plan for this project is shown on plates 4-1 and 4-2. The initial construction area consisted of 14 segments of composite revetment totalling 3,510 linear feet, 13 windrow refusal structures totalling 636 linear feet, one system of 2 hardpoints, two systems of 3 hardpoints, and three systems of 1 hardpoint each. Due to extensive erosion between structures a modification was implemented to construct 4 additional segments of composite revetment totalling 1,140 linear feet and one 50-foot windrow refusal. Typical sections of the structure types used in this project are shown on plates 4-3 and 4-4. All segments of composite revetment constructed are Case I. All windrow refusals are Type II except Ref. 782.59, 775.91, and 784.95, which are Type I. All stone roots are Type A except the roots for Hardpoint 785.95 and 785.85, which are Type B. Elevations for stone roots represent the top elevation of the root at the most landward point. The crown width on each hardpoint spur is 5.0 feet. Construction in this contract was accomplished with floating plant.

Table 3-20 provides a construction program which includes material quantities and costs by structure. Low grade material did not display sufficient economic advantage as a bid item for this contract; therefore, all structures in this project were constructed of durable stone. Tables 3-18 and 3-19 display the specified stone gradations.

Table 3-18

STONE FOR UPPER BANK PAVING, WINDROW REVETMENT AND REFUSALS, AND HARDPOINT SURFACING AND ROOTS

Weight per Stone	Percent of Total Weight Lighter than or Passing
200-lbs	100
50-lbs	35-60
2-inch screen	0-15

Table 3-19

STONE FOR REVETMENT TOE AND HARDPOINT CORE

Weight per Stone	Percent of Total Weight Lighter than or Passing
500-lbs	100
165-lbs	35-60
3-inch screen	0-15

Bulk specific gravity, saturated surface-dry basis Method CRD-C 107-69, required not less than 2.40. Soundness in magnesium sulfate, ASTM Standard C88-76, required a loss at 5 cycles of not more than 12 percent. Soundness in freezing and thawing for ledge rock, Method Modified Designation T 103-42, required a loss at 12 cycles of not more than 10 percent.

Stone application rates in average tons per linear foot by structure type for this project site are as follows.

Composite Revetment	4.5
Windrow Refusal	4.0
Hardpoints	6.0

Photos 27 through 30 show composite revetments before and after construction. Photos 31 and 32 show a composite revetment and hardpoint after completion.

Table 3-20

VERMILLION BOAT CLUB CONSTRUCTION PROGRAM

Struc. No.	Type**	Length (ft)	Date Start	Date Finish	Stone (Tons)	L.G.M. (Tons)	Gravel (Tons)	Cost ($)	$/L.F.
786.1*	HP	100	7/30/78	7/31/78	344	238		4,186.50	41.87
786.01*	WRF	50	8/28/78	8/28/78	191			1,910.00	38.20
786.0*	CR	300	8/28/78	8/31/78	1,345			13,450.00	44.83
785.81*	WRF	50	8/31/78	8/31/78	195			1,462.50	29.25
785.8* 0+00 to 2+00	CR	600	9/01/78	9/08/78	1,703	679		21,020.75	35.03
785.6*	HP	80	9/14/78	9/15/78	306	152		3,321.00	41.51
785.45*	HP	60	9/12/78	9/14/78	224	158		2,746.50	45.78
785.3*	HP	60	9/19/78	9/19/78	204	158		2,596.50	43.28
785.11*	WRF	50	9/20/78	9/20/78	203			1,522.50	30.45
785.1* 0+00 to 2+00	CR	200	9/20/78	9/27/78					
7+00 to 9+00	CR	200	9/20/78	9/27/78	437	1,210		11,445.00	28.61
784.95*	WRF	50	9/23/78	9/25/78	172			1,290.00	25.80
784.8*	HP	100	9/28/78	9/29/78	347	258		4,344.00	43.44
784.7*	HP	80	9/30/78	10/02/78	263	360		4,402.50	55.03
784.61*	HP	80	10/02/78	10/03/78	253	240		3,517.50	43.97
784.6* 10+00 to 13+00	CR	300	10/04/78	10/06/78	225	1,141		9,389.25	31.30
784.48*	WRF	50	10/04/78	10/04/78	190			1,425.00	28.50
784.31*	HP	80	10/07/78	10/07/78	243	314		3,955.00	49.44
784.3* 6+00 to 8+00	CR	200	7/12/78	7/14/78		803	91	6,102.75	30.51
784.15*	WRF	50	7/12/78	7/12/78	203			1,522.50	30.45
784.0*	HP	100	6/23/78	6/23/78	344	114		3,349.50	33.50
783.91*	WRF	40	6/23/78	6/23/78	166			1,245.00	31.13
783.9*	CR	300	6/23/78	7/17/78	275	1,078	116	10,209.00	34.03
783.71*	WRF	50	6/22/78	6/22/78	195			1,462.50	29.25
783.7*	CR	200	6/22/78	7/17/78	228	674	87	6,912.00	34.56
783.6*	HP	60	6/22/78	6/22/78	222	107		2,387.25	29.79
783.5*	HP	60	7/03/78	7/03/78	215	99		2,280.75	38.01

Table 3-20 (Cont'd)

VERMILLION BOAT CLUB CONSTRUCTION PROGRAM

Struc. No.	Type**	Length (ft)	Date Start	Date Finish	Stone (Tons)	L.G.M. (Tons)	Gravel (Tons)	Cost ($)	$/L.F.
783.41*	WRF	50	7/18/78	7/18/78	193			1,447.50	28.95
783.4*	CR	250	7/13/78	7/18/78	226	978	111	9,129.00	36.52
783.11*	WRF	50	6/22/78	6/22/78	190			1,425.00	28.50
783.1*									
0+00 to 3+00	CR	300	7/27/78	8/01/78					
3+80 to 4+30	CR	50	7/27/78	8/01/78	188			1,880.00	37.60
7+30 to 10+90	CR	360	7/27/78	8/01/78	492	2,484	263	22,429.50	33.98
782.95*	WRF	50	7/28/78	7/28/78	208			1,560.00	31.20
782.7*									
1+80 to 2+10	CR	390	8/06/78	8/14/78	472		37	4,997.50	12.81
7+00 to 9+00	CR	200	8/06/78	8/14/78					
11+00 to 14+00	CR	300	8/06/78	8/14/78	752	2,887	318	27,512.25	55.02
782.59*	WRF	46	7/24/78	7/24/78	214			1,605.00	34.89
782.51*	WRF	50	8/09/78	8/10/78	207			1,552.50	31.05
782.3*	CR	250	8/14/78	8/18/78	224	906	101	8,553.00	34.21
782.01*	WRF	50	8/18/78	8/18/78	197			1,477.50	29.55
782.0*	CR	250	8/21/78	8/23/78	248	1,143	103	10,347.75	41.39

SUBTOTAL	$221,400
Clearing and Grubbing	3,200
Seeding and Mulching	600
Monitoring and Evaluation	650
	5,100
Engineering and Design	45,000
Supervision and Administration	12,000
TOTAL COST	$288,000

*Designated by 1960 River Mileage

**WRF = Windrow Refusal; HP = Hardpoint, CR = Composite Revetment

Low grade material was bid on this job; however, quality stone was substituted.

PHOTO 27. SITE OF COMPOSITE REVETMENT 782.7* STATION 0+00 PRIOR TO CONSTRUCTION, LOOKING D/S (Photo Taken 3 August 1978)

PHOTO 28. COMPOSITE REVETMENT 782.7* STATION 0+00 AFTER COMPLETION, LOOKING D/S (Photo Taken 13 August 1978)

PHOTO 29. SITE OF COMPOSITE REVETMENT 782.7* STATION 9+00 PRIOR TO CONSTRUCTION, LOOKING U/S (Photo Taken 25 July 1978)

PHOTO 30. COMPOSITE REVETMENT 782.7* STATION 9+00 AFTER COMPLETION, LOOKING U/S (Photo Taken 16 August 1978)

VERMILLION BOAT CLUB AREA
Photos 29 and 30

PHOTO 31. COMPOSITE REVETMENT 785.1* APPROXIMATELY 12 MONTHS AFTER COMPLETION, LOOKING U/S
(Photo Taken 5 October 1979)

PHOTO 32. VEGETATED HARDPOINT 784.8* APPROXIMATELY ONE YEAR AFTER COMPLETION
(Photo Taken 6 October 1979)

5. **BROOKY BOTTOM ROAD PROJECT AREA**. The general plan for this project is shown on plates 5-1 and 5-2. The initial construction consisted of 6 segments of composite revetment totalling 2,395 linear feet, 2 segments of windrow revetment totalling 800 linear feet, 8 windrow refusals totalling 771 linear feet, and three hardpoint systems consisting of 3, 4, and 6 hardpoints respectively. The construction of additional structures was necessitated due to severe erosion conditions at unprotected areas at the demonstration site. Modification No. 2 involved an additional 588 linear feet of composite revetment and 224 linear feet of windrow refusal. Modification No. 3 involved an additional 150 linear feet of composite revetment, 10 linear feet of windrow refusal, and 17 hardpoints. The hardpoints were distributed among the existing systems so the system farthest upstream now consists of 11 hardpoints. The center system consists of 5 hardpoints and the system farthest downstream consists of 14 hardpoints. Typical sections of the structure types used in this project are shown on plate 5-3.

Four types of composite revetment are represented in the Brooky Bottom demonstration site. Composite revetment Type A is demonstrated in structures 785.5, station 13+00 to 16+00, and 784.59, station 7+00 to 10+50. Composite revetment Type B is represented by structures 785.5, station 16+00 to 18+00; 784.59, station 0+00 to 5+00; 783.20, station 0+00 to 3+95; 785.69 and 784.94. Composite revetment 783.20, station 18+50 to 19+00 is Type C. Structures 783.20, station 16+00 to 18+50 and 23+00 to 27+00, 783.20, station 20+00 to 22+00 and 27+00 to 28+75 are Type D. Windrow Revetment 785.5, station 0+00 to 3+00 is Type I, while station 5+50 to 10+50 of the same structure is Type II. All hardpoint roots are Type A except the roots on Hardpoints 784.2 and 783.9. These two roots are Type B. For differentiation, both types of hardpoint roots are shown on plate 5-3. Mandatory floating plant was required on specified structures in this contract.

Table 3-23 provides a construction program which includes material quantities and costs by structure. Low grade material did display sufficient economic advantage as a bid item for this contract.

Tables 3-21 and 3-22 display the specified gradation requirements for the material utilized in the structures.

Table 3-21

STONE FOR UPPER BANK PAVING, WINDROW REVETMENT AND REFUSALS, AND HARDPOINT SURFACING AND ROOTS

Weight per Stone	Percent of Total Weight Lighter than or Passing
200-lbs	100
50-lbs	35-60
2-inch screen	0-15

Table 3-22

STONE FOR COMPOSITE REVETMENT TOE AND HARDPOINT CORE

Weight per Stone	Percent of Total Weight Lighter than or Passing
500-lbs	100
165-lbs	35-60
3-inch screen	0-15

The stone material was required to meet the following standards:

Bulk specific gravity, saturated surface-dry basis Method CRD-C 107-69, required not less than 2.40. Soundness in magnesium sulfate, ASTM Standard C88-73, required a loss at 5 cylces of not more than 12 percent. Soundness in freezing and thawing for ledge rock, Method Modified AASHTO Designation T 103-42, required a loss of 12 cycles of not more than 10 percent.

Stone application rates in average tons per linear foot by structure type for this project site are as follows.

Composite Revetment	4.5
Windrow Revetment	3.6
Windrow Refusal	4.2
Hardpoints	5.6

Typical severe bankline erosion conditions at the Brooky Bottom Road area are shown in Photos 33 and 34. Photos 35 and 36 show an example of a composite revetment Type A. Photos 37 through 40 show the construction sequence of Windrow Revetment 785.5. Photos 41 and 42 demonstrate two structure types approximately 2-plus years after completion.

Table 3-23

BROOKY BOTTOM ROAD

CONSTRUCTION PROGRAM

Struc. No.	Type*	Length (ft)	Date Start	Date Finish	Stone (Tons)	L.G.M. (Tons)	Excav. (CY)	Gravel (Tons)	Other	Cost ($)	$/L.F.
786.4*	HP	90	10/20/78	11/21/78	307	294				6,979.08	77.55
786.3*	HP	140	10/20/78	11/21/78	353	250				7,137.24	50.98
786.2*	HP	80	10/20/78	11/21/78	312	260				6,701.76	83.77
786.11*	HP	80	10/21/78	11/21/78	289	270				6,501.72	81.27
786.02*	HP	110	1/05/77	4/05/77	213	394	156			5,302.66	48.21
785.02*	HP	60	10/21/78	11/21/78	277	170				5,336.76	88.95
785.85*	HP	70	10/21/78	11/22/78	296	150				5,383.60	76.91
785.82*	HP	110	1/04/77	2/02/77	224	271	307			4,522.09	41.11
785.7*	WRF	84	12/16/76	1/27/77	315		337			3,242.57	38.60
785.69*	CR	163	1/27/77	2/02/77	108	339	595			4,135.55	25.37
785.65*	HP	60	11/22/78	11/22/78	179	150				3,853.32	64.22
785.61*	HP	100	1/05/77	4/01/77	130	247	77			3,280.99	32.81
785.57*	HP	50	11/01/78	11/22/78	219	150				4,376.52	87.53
785.51*	WRF	100	12/06/76	12/09/76	451		370			4,574.61	45.75
785.5*											
0+00											
to											
3+00	WR	300	12/11/76	1/21/77	425	643	1,097			9,940.01	33.13
5+50											
to											
10+50	WR	500	12/13/76	1/24/77	501	1,299	1,797			16,373.91	32.75
13+00											
to											
18+00	CR	500	3/10/77	3/31/77		2,382	2,112			22,373.88	44.75
785.31*	WRF	100	12/09/76	12/21/76	455		411			4,632.08	46.32
785.2*	WRF	101	12/15/76	1/05/77	462		551			4,789.61	47.42
785.1*	HP	53	3/01/77	7/19/77	175	222	138			3,545.70	66.90
785.0*	HP	70	1/04/77	2/04/77	164	189	138			3,176.93	45.38
784.96*	WRF	10	10/19/78	10/21/78	40					523.20	52.32
784.94*	CR	150	10/19/78	10/21/78	104	434				5,735.04	38.23
784.9*	HP	72	1/04/77	2/08/77	164	144	137			2,810.86	39.04
784.81*	HP	60	11/01/78	11/22/78	239	150				4,638.12	77.30
784.71*	HP	115	12/22/76	2/04/77	218	251	342			4,316.35	37.53
784.62*	WRF	100	12/15/76	12/16/77	439		542			4,570.44	45.70

Table 3-23 (Cont'd)

BROOKY BOTTOM ROAD

CONSTRUCTION PROGRAM

Struc. No.	Type*	Length (ft)	Date Start	Date Finish	Stone (Tons)	L.G.M. (Tons)	Excav. (CY)	Gravel (Tons)	Other	Cost ($)	$/L.F.
784.59*											
0+00											
to											
5+00	CR	500	7/01/77	7/07/77		1,988				15,904.00	31.81
7+00											
to											
10+50	CR	350	7/08/77	7/18/77		1,388	1,015	431		16,632.00	47.52
784.4*	WRF	100	12/17/76	12/18/76	442.86		790			4,764.96	47.65
784.2*	HP	110	1/06/77	2/28/77	292.84	394	283			6,146.09	55.87
784.1*	HP	60	11/01/78	11/22/78	247	150				4,742.76	79.05
784.01*	HP	60	11/01/78	11/22/78	238	150				4,625.04	77.08
783.92*	HP	100	2/10/76	1/07/77	281	118	307			3,846.29	38.46
783.8*	HP	80	2/11/76	1/06/77	178	140	158			2,934.24	36.68
783 72*	HP	105	1/06/77	2/17/77	296	123	303			4,023.49	38.32
783.61*	HP	95	12/22/76	2/15/77	176	107	155			2,648.06	27.87
783.51*	HP	109	12/21/76	2/16/77	310	132	272			4,213.04	38.65
783.45*	HP	80	11/01/78	11/22/78	282	214				5,845.68	73.07
783.42*	HP	80	11/03/78	11/24/78	281	217				5,862.84	73.29
783.34*	HP	40	11/03/78	11/24/78	147	250				4,442.76	111.07
783.30*	HP	30	11/03/78	11/24/78	130	250				4,220.40	140.68
783.27*	HP	40	11/03/78	11/24/78	180	150				3,866.40	97.00
783.25*	HP	30	11/03/78	11/24/78	222	160				4,516.56	150.55
783.21*	WRF	100	12/18/76	12/20/76	408		605			4,307.75	43.08
783.20*											
0+00											
to											
3+95	CR	395	4/06/77	4/18/77		1,814	2,352			16,040.80	40.61
16+00											
to											
19+00	CR	300	6/03/77	6/29/77		1,617	1,433		FC40-8	17,103.60	57.00
20+00											
to									FC		
22+00	CR	200	6/06/77	6/24/77		1,016	1,231		342 sy	11,657.20	58.29
23+00											
to									FC		
28+75	CR	575	6/09/77	7/13/77		2,826	3,173	175	50 sy	[illegible]	49.50
783.12*	WRF	70	1/13/77	1/18/77	222		655			2,552.82	36.47
783.05*	WRF	40	1/31/77	2/01/77	130		386			1,501.49	37.54

Table 3-23 (Cont'd)

BROOKY BOTTOM ROAD

CONSTRUCTION PROGRAM

Struc. No.	Type*	Length (ft)	Date Start	Date Finish	Stone (Tons)	L.G.M. (Tons)	Excav. (CY)	Gravel (Tons)	Other	Cost ($)	$/L.F.
783.0*	WRF	100	12/20/76	12/22/786	428		640			4,520.38	45.20
782.9*	WRF	100	1/20/77	1/26/77	433		756			4,647.14	46.47

SUBTOTAL	$349,000.00
Clearing and Grubbing	6,000.00
Seeding	4,000.00
Monitoring	14,000.00
Pile Removal	6,000.00
Supervision and Administration	27,000.00
Engineering and Design	19,000.00
TOTAL COST	$425,000.00

*Designated by 1960 River Mileage

**WRF = Windrow Refusal; HP = Hardpoint;
CR = Composite Revetment; WR = Windrow Revetment

PHOTO 33. TYPICAL SEVERE EROSION CONDITIONS AT RIVER MILE 783.2*
(Photo Taken 12 April 1977)

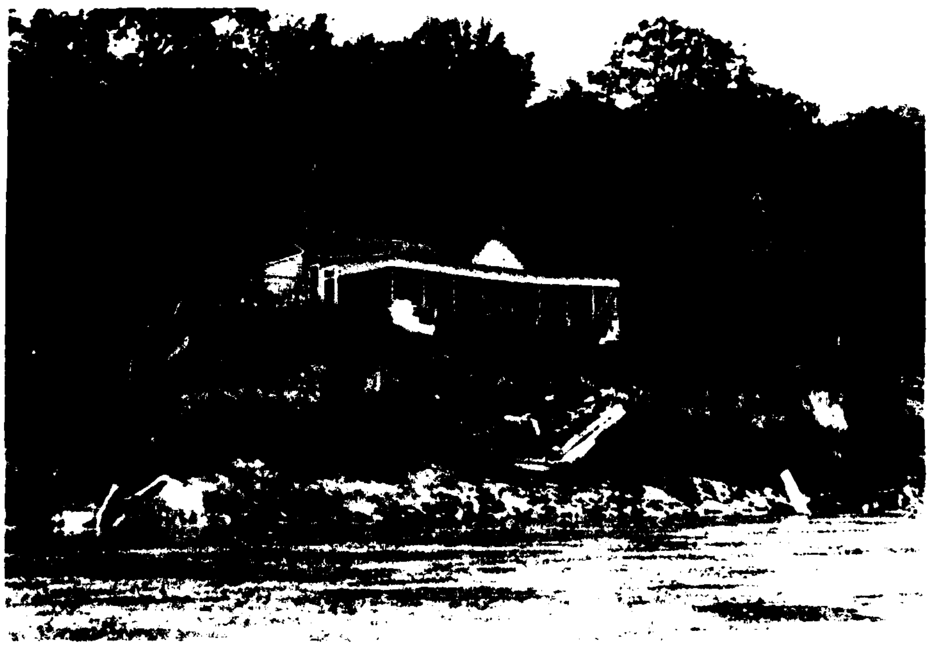


PHOTO 34. SEVERE BANKLINE EROSION CONDITIONS AT RIVER MILE 786.2*
(Photo Taken 5 October 1979)

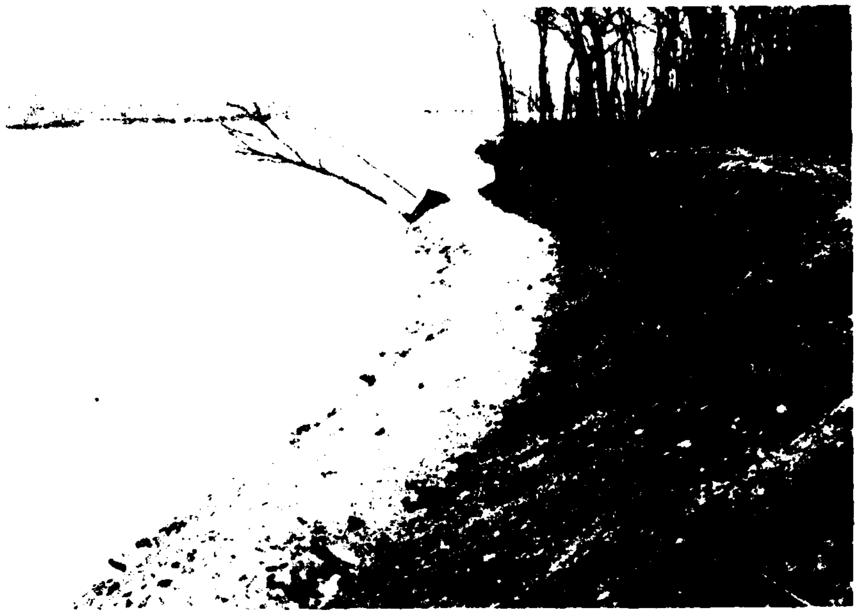


PHOTO 35. COMPLETED COMPOSITE REVETEMENT 784.59*, STATION 7+00 TO 10+15 SHOWING THE LOW GRADE MATERIAL (CHALK) TOE WITH AN UPPER BANK GRAVEL COVER, LOOKING D/S
(Photo Taken 12 April 1977)

PHOTO 36. COMPOSITE REVETMENT 784.59*, STATION 7+00 TO 10+15 18 MONTHS AFTER COMPLETION
(Photo Taken 26 October 1977)

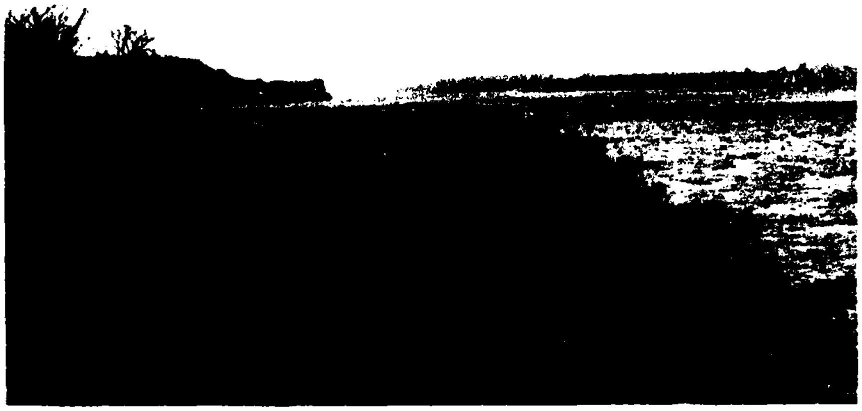


PHOTO 37. SITE OF WINDROW REVETMENT 785.5* PRIOR TO CONSTRUCTION, LOOKING U/S
(Photo Taken 11 November 1976)

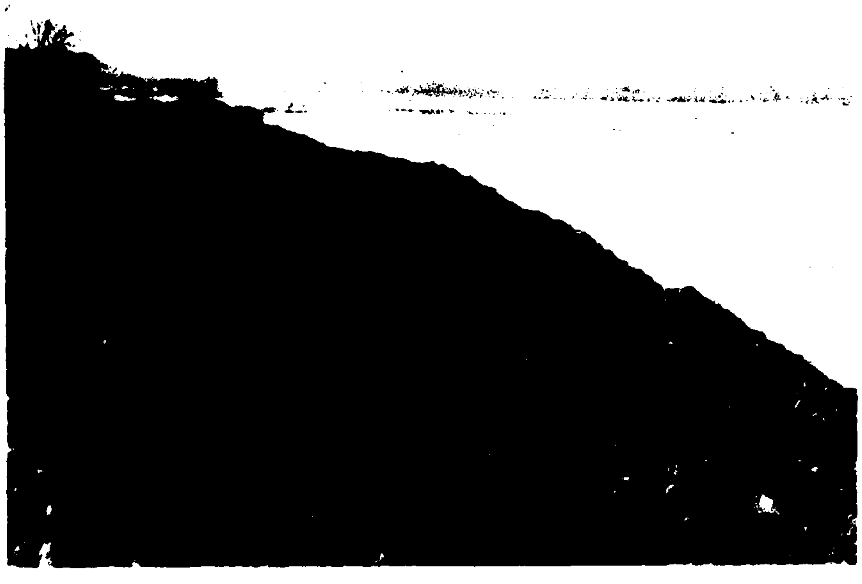


PHOTO 38. WINDROW REVETMENT 785.5* AFTER STONE PLACEMENT AND PRIOR TO CHALK PLACEMENT, LOOKING U/S
(Photo Taken 13 December 1976)

Table 1-33
PRETTY POINT (PHASE I)
CONSTRUCTION SCHEDULE

STRUCTURE	BANK	LENGTH (FEET)	STATION TO STATION	DESCRIPTION	C.R.P. ELEV.	STONE (TONS)	STONE GRADATION	ESTIMATED QUANTITIES: STONE OR LOW GRADE MATRL. (TONS)	ESTIMATED QUANTITIES: EXCAVATION (C.Y.)	ESTIMATED QUANTITIES: GRAVEL (TONS)
REF. 1343.72	R	50	2+30 to 2+80	Windrow Refusal	1674.3	300	C	---	225	---
REF. 1343.71	R	500	0+00 to 5+00	Reinforced Revetment -Type II (Tieback interval @ 100')	1647.3	550	C	2250	1500	300
REF. 1343.60	R	50	3+70 to 4+20	Windrow Refusal	1647.2	300	C	---	225	---
REV. 1343.59	R	400	0+00 to 4+00	Windrow Revetment -Type A (4.5 t/lf)	1647.2	1800	C	---	1600	---
	R	500	7+00 to 12+00	Windrow Revetment -Type A (3.5 t/f)	1647.1	1750	C	---	1500	---
REF. 1343.46	R	50	3+05 to 3+55	Windrow Refusal	1647.1	300	C	---	225	---
REF. 1343.34	R	50	4+75 to 5+25	Windrow Refusal	1647.0	300	B	---	225	---
REV. 1343.33	R	500	0+00 to 5+00	Composite Revetment	1647.0	1000	B	1250	---	300
	R	600*	8+00 to 14+00	Composite Revetment	1646.9	1200	B	1500	---	300
REF. 1343.26	R	50	1+80 to 2+30	Windrow Refusal	1646.9	300	B	---	225	---

NOTES: (1) CRP refers to the Construction Reference Plane elevation as defined in Section II.B.1.b.

(2) Stone Gradations A, B, and C refer to stone sizes and weights as defined in Table 1-25.

PHOTO 41. WINDROW REVETMENT 785.5* APPROXIMATELY TWO YEARS AND NINE MONTHS AFTER COMPLETION, LOOKING U/S
(Photo Taken 5 October 1979)

PHOTO 42. L-SHAPED HARDPOINT 785.82* TWO YEARS AND SEVEN MONTHS AFTER COMPLETION, LOOKING U/S
(Photo Taken 5 October 1979)

6. **MULBERRY BEND PROJECT AREA**. The general plan for this project is shown on plate 7-1. Initial construction consisted of 9 segments of composite revetment totalling 2,150 linear feet, 4 windrow refusal structures totalling 278 linear feet, and one 640-foot stone filled vane dike.

In the initial construction all windrow refusals are Type II, except Ref. 775.91 which is Type I. Plate 7-2 depicts the typical sections for these windrow refusals.

Construction modification later changed design specifications for the Mulberry Bend area. One such change concerned the vane dike structure which was a component of the earth core dike design. It was originally intended to reduce the volume of flow in the earth core dike construction zone which would then form a channel block connecting to a large sandbar in the channel. By reducing the requirements for the material utilized in the structure's volume of flow, the river would have been almost completely diverted to the left side of the sandbar thus providing a quiet water area downstream of the blocked channel. During and after construction of the vane dike the flow conditions scoured a deeper channel in the vicinity of the vane dike and along the right side of the sandbar. Construction was started on the earth core dike but prevailing conditions such as the channel depth, high velocity, and a change in river conditions prevented the earth core dike from being completed as designed. The structure was shortened to function as a dike but bankline revetment structures downstream of the proposed construction were redesigned to accommodate this modification. Other modifications included the addition of 250 linear feet of windrow refusal, 1,425 linear feet of composite revement, 300 linear feet of reinforced revetment, and 1,600 linear feet of composite revetment was replaced by the same length of reinforced revetment. Plates 7-2 and 7-3 show typical sections of the structures at the Mulberry Bend project area. Mandatory floating plant was required only for the initial vane dike construction and subsequent construction pertaining to the modifications of that structure.

Table 3-29 provides a construction program which includes material quantities and costs by structure. Low grade material did display sufficient economic advantage as a bid item for this contract; therefore, all structures in this project were constructed of durable stone in combination with low grade material in such proportions as to support the engineering integrity of the structures. Tables 3-24 through 3-28 display the specified gradation.

The stone material was required to meet the following standards: Bulk specifc gravity, saturated surface-dry basis Method CRD-C 107-69, required not less than 2.40. Soundness in magnesium sulfate, ASTM Standard C 88-73, required a loss at 5 cycles of not more than 12 percent. Soundness in freezing and thawing for ledge rock, Method Modified AASHTO Designation T 103-42, required a loss of 12 cycles of not more than 10 percent.

Table 3-24

STONE FOR COMPOSITE REVETMENT TOE (UPPER), REINFORCED REVETMENT TIEBACKS, AND WINDROW REFUSALS

Weight or Size per Stone	Percent of Total Weight Lighter than or Passing
200-lbs	100
50-lbs	35-60
2-inch screen	0-15

Table 3-25

STONE FOR COMPOSITE REVETMENT TOE (LOWER), REINFORCED REVETMENT TOE, AND VANE DIKE

Weight or Size per Stone	Percent of Total Weight Lighter than or Passing
500-lbs	100
165-lbs	35-60
3-inch screen	0-15

Table 3-26

LOW GRADE MATERIAL, GRADATION A

(When Specific Gravity is 1.70 to 2.10)

Weight per Piece	Percent of Total Weight Lighter than or Passing
150-lbs	100
50-lbs	35-60
3-inch screen	0-25

(When Specific Gravity equals or exceeds 2.10)

Weight per Piece	Percent of Total Weight Lighter than or Passing
200-lbs	100
60-lbs	35-60
3-inch screen	0-25

Table 3-27

LOW GRADE MATERIAL, GRADATION B

Weight per Piece	Percent of Total Weight Lighter than or Passing
400-lbs	100
150-lbs	35-60
25-lbs	0-25

Table 3-28

GRADATION OF GRAVEL MATERIAL

Sieve Size	Percent Passing
3-inch	90-100
1½-inch	55-80
3/4-inch	30-55
3/8-inch	15-35
No. 4	0-10

Sources of low grade material such as softer sandstone, limestones, and chalk were available relatively near the project site. It was determined that such material is acceptable to provide the bulk necessary in the toe of revetments and the fill in vane dikes. The low grade material was reasonably well graded from coarse to fine. Dirt and fines of less than ½-inch maximum cross section, accumulated from interledge layers or from blasting or handling operations, did not exceed 15 percent by weight. Occassional pieces slightly larger than the maximum size were permitted, provided the gradation was not affected.

Stone application rates in average tons per linear foot by structure type for this project site are as follows.

Reinforced Revetment	4.3
Composite Revetment	5.6
Windrow Refusal	4.0

Photos 43 through 46 show photographs of composite revetment 775.9 taken at four stations along the structure. Photos 47 and 48 depict composite revetment 774.9 during construction and immediately after completion.

Table 3-29

MULBERRY BEND CONSTRUCTION PROGRAM

Struc. No.	Type**	Length (ft)	Date Start	Date Finish	Stone (Tons)	L.G.M. (Tons)	Excav. (CY)	Gravel (Tons)	Cost ($)	$/L.F.
775.91*	WRF	103	5/18/78	5/19/78	405				3,037.50	29.49
775.9*	CR		5/24/78	7/06/78	1,121	12,764		456	97,984.50	54.44
0+00 to 12+00	CR	1,200								
14+50 to 19+00	CR	450								
24+00 to 25+50	CR	150								
775.61*	WRF	50	6/11/78	6/11/78	210				1,575.00	31.50
775.41*	WRF	75	6/09/78	6/09/78	297				2,227.50	29.70
775.4*	SFVD	640	6/14/78	7/11/79		9,291			62,714.25	97.99
774.91*	WRF	50	1/24/79	1/25/79		200	168		2,982.00	59.64
774.9*										
0+00 to 5+50	CR	550	1/16/79	2/07/79		1,893			19,876.50	36.14
7+00 to 17+50	CR	1,050	1/16/79	2/07/79		3,600			39,900.00	38.00
17+50 to 31+50	CR	1,400	3/17/80	5/20/80	3,493	1,890		856	88,407.80	63.15
774.81*	WRF	50	1/22/79	1/23/79		200	167		2,976.75	59.54
774.71*	WRF	50	5/27/78	5/27/78	200				1,500.00	30.00
774.7*	CR	475	6/02/78	6/15/78	453	2,059		193	19,569.25	41.20
774.61*	WRF	50	6/11/78	6/11/78	200				1,794.00	35.88
774.6*										
0+00 to 5+50	CR	550	6/11/78	6/14/78	450	2,344		220	23,293.30	42.35

SUBTOTAL	367,800
Clearing and Grubbing	4,550
Seeding and Mulching	650
Monitoring	46,000
Engineering and Design	40,000
Supervision and Administration	25,000
TOTAL COST	$485,000

*Designated by 1960 River Mileage

*WRF - Windrow Refusal; Ck - Composite Revetment, Stone Fill Vane Dike

RR - Reinforced Revetment

Table 3-30

MULBERRY BEND CONSTRUCTION PROGRAM (RECONSTRUCTION)

Struc. No.	Type**	Length (ft)	Date Start	Date Finish	Stone (Tons)	L.C.M. (Tons)	Excav. (CY)	Gravel (Tons)	Cost ($)	$/L.F.
774.9	RR									
0+00 to 5+50		550	3/17/80	5/20/80	413	550		330	18,129.80	32.96
7+00		1,050	3/17/80	5/20/80	787	1,050		630	34,590.20	32.94

SUBTOTAL	52,800
Clearing and Grubbing	2,200
Photography	200
Cross-Section	1,000
TOTAL COST	$56,200

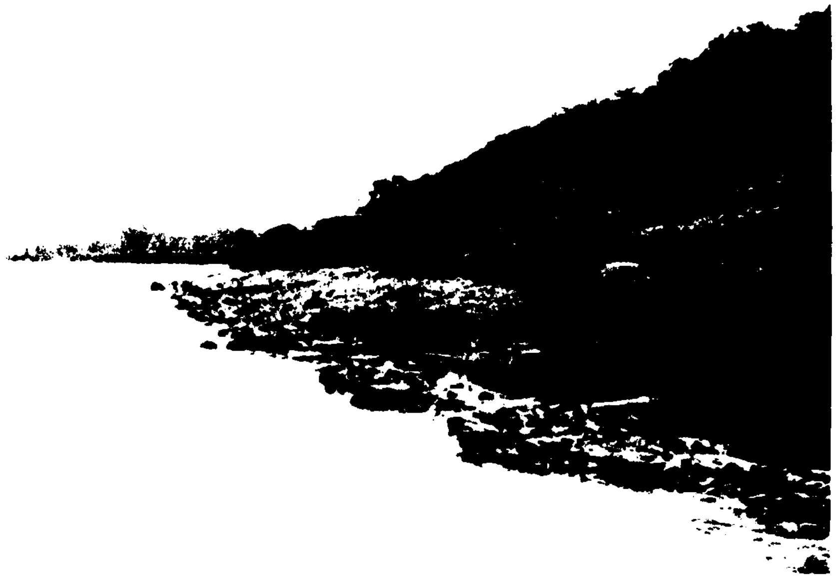


PHOTO 43. COMPOSITE REVETMENT 775.9* STATION 6+00, LOOKING D/S. LOW GRADE MATERIAL TOE FILL PLACED RIVERWARD AND PARALLEL TO THE BANKLINE (Photo Taken 6 August 1978)

PHOTO 44. COMPOSITE REVETMENT 775.9*, STATION 12+00, LOOKING U/S. LOW GRADE MATERIAL USED FOR TOE FILL. NO UPPER BANK SLOPE PROTECTION WAS USED AT THIS SITE (Photo Taken 6 August 1978)

PHOTO 45. COMPOSITE REVETMENT 775.9* STATION 16+00, LOOKING D/S.
TOE FILL OF LOW GRADE MATERIAL COVERED WITH A THIN GRAVEL BLANKET
(Photo Taken 6 August 1978)

PHOTO 46. COMPOSITE REVETMENT 775.9* IMMEDIATELY DOWNSTREAM OF
REFUSAL 775.4*, DEMONSTRATES USE OF LOW GRADE TOE FILL COVERED WITH A
THIN GRAVEL BLANKET
(Photo Taken 5 October 1979)

PHOTO 47. COMPOSITE REVETMENT 774.9* DURING CONSTRUCTION. TOE CONSTRUCTED ENTIRELY OF LOW GRADE MATERIAL AND COVERED WITH A THIN LAYER OF GRAVEL (Photo Taken 14 May 1980)

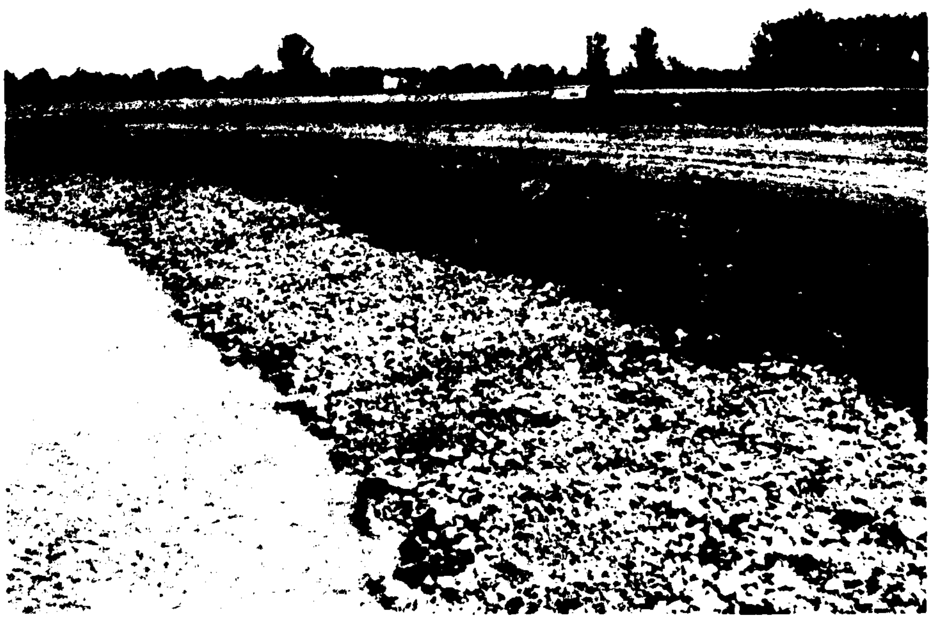


PHOTO 48. COMPOSITE REVETMENT 774.9*, IMMEDIATELY AFTER STRUCTURE COMPLETION (Photo Taken 12 May 1980)

MULBERRY BEND AREA
Photos 47 and 48

7. **VERMILLION RIVER CHUTE PROJECT AREA.** The general plan for this project is shown on plate 8-1. Initial construction consisted of 4 segments of windrow revetment totalling 3,328 linear feet, 7 windrow refusals totalling 489 linear feet, and one system of 3 hardpoints. Additional structures were constructed by modifications to existing construction contracts.

The construction was necessitated by severe erosion conditions at unprotected areas of the demonstration site. These structures consisted of 4,655 linear feet of composite revetment, 500 linear feet of windrow revetment, 310 linear feet of windrow refusal, 1,500 linear feet of reinforced revetment, and 2 systems of hardpoints with 2 hardpoints each. Repairs on existing construction involved 900 linear feet of windrow revetment and 25 linear feet of windrow refusal. Typical sections of the structure types used in this project are shown on plate 8-2.

All windrow revetment in the initial construction contract is Type I with the exception of a field modification at structure 770.1, station 2+00 to 4+00 changing it to a Type II. The roots for HP 769.8, HP 769.75, and HP 769.72 were also field modified to Type B instead of Type A as originally designed. All other hardpoint roots in subsequent construction are Type A. Mandatory floating plant was required on specified structures in this contract because a portion of the construction required under this contract was in areas of significant environmental and/or recreational value. Table 3-33 provides a construction program which includes material quantities and costs by structure. Low grade material did not display sufficient economic advantage as a bid item for this contract; therefore, all structures in this project were constructed of durable stone. Tables 3-31 and 3-32 display the specified gradation requirements for the material utilized in the structures.

Table 3-31

STONE FOR UPPER BANK PAVING, WINDROW REVETMENT AND REFUSALS, AND HARDPOINT SURFACING AND ROOT

Weight per Stone	Percent of Total Weight Lighter than or Passing
200-lbs	100
50-lbs	35-60
2-inch screen	0-15

Table 3-32

STONE FOR COMPOSITE REVETMENT TOE AND HARDPOINT CORE

Weight per Stone	Percent of Total Weight Lighter than or Passing
500-lbs	100
165-lbs	35-60
3-inch screen	0-15

The stone material was required to meet the following standards: Bulk specific gravity, saturated surface-dry basis Method CRD-C 107-69, required not less than 2.40. Soundness in magnesium sulfate, ASTM Standard C88-73, required a loss at 5 cylces of not more than 12 percent. Soundness in freezing and thawing for ledge rock, Method Modified AASHTO Designation 103-42, required a loss of 12 cycles of not more than 10 percent.

Stone application rates in average tons per linear foot by structure type for this project site are as follows.

Reinforced Revetment	4.4
Composite Revetment	4.7
Windrow Revetment	4.1
Windrow Refusal	5.0
Hardpoints	5.9

Photo 49 displays typical bankline erosion along the Vermillion River Chute area. Composite revetment structures are shown in photos 50 and 51. Photo 52 shows a typical hardpoint after completion. Photos 53 through 59 display windrow revetment 771.9 over a period of time after completion.

Table 3-33

VERMILLION RIVER CHUTE CONSTRUCTION PROGRAM

Struc. No.	Type**	Length (ft)	Date Start	Date Finish	Stone (Tons)	L.G.M. (Tons)	Excav. (CY)	Gravel (Tons)	Other	Cost ($)	$/L.F.
771.91*	WRF	85	2/17/77	2/18/77	333		112			5,780.27	68.00
771.9*											
0+00 to 12+00	CR	1,200	7/17/78	10/17/78	484	6,185	4,748		Filter Cloth 500 sy	50,467.85	42.06
25+00 to 45+70	WR	2,070	2/15/77	5/14/77	9,391		9,645			106,664.79	51.53
45+70 to 49+70	CR	400	8/22/78	11/03/78		2,420		143		21,731.49	54.33
52+50 to 65+00	CR	1,250	7/17/78	10/17/78	503	4,788		518		38,603.50	30.88
771.4*	WRF	100	2/14/77	2/18/77	314		311			5,553.16	55.53
770.9*	WRF	91	2/16/77	2/17/77	441		314			7,737.59	85.03
770.85*	HP	100	11/06/78	1/10/79	423	267	388	30		9,055.48	90.55
770.8*	HP	60	11/07/78	1/10/79	242	154	258	20		5,297.82	88.30
770.71*	WRF	50	11/06/78	11/08/78	205		195			3,166.65	63.33
770.7*	RR	400	12/01/78	12/14/78	206	1,456	827			16,656.65	41.64
770.65*	HP	60	11/08/78	12/14/78	250	151	267	20		5,399.21	89.99
770.6*	HP	60	11/08/77	12/14/78	251	157	165	20		5,247.57	87.46
770.51*	WRF	50	11/08/78	11/10/78	220		194			3,366.14	67.32
770.5*											
0+00 to 4+00	RR	400	12/08/78	1/11/79	248	1,499	453			16,790.61	41.98
7+00 to 10+00	RR	300	12/08/78	1/11/79	227	1,261	453			14,523.45	48.41
13+00 to 17+00	RR	400	12/08/78	1/11/79	222	1,535	454			16,743.52	41.86
770.4*	WRF	50	11/09/78	11/09/78	219	194				3,352.70	67.05
770.3*	WRF	50	11/09/78	11/09/78	210	194				3,231.74	64.63
770.11*	WRF	51	2/19/77	2/19/77	249		177			4,368.81	85.66
770.1*											
0+00 to 12+58	WR	1,258	5/07/77	5/14/77	1,258	3,864	5,739			56,140.68	45.00
29+00 to 32+00	CR	300	8/15/77	9/02/77		1,260	1,733	300		16,703.00	55.68
35+00 to 38+00	CR	300	8/18/77	9/01/77		1,534	1,869			16,442.00	54.81
41+00 to 44+65	CR	365	8/24/77	9/05/77		1,446	2,704	153	Willow Veg 300 sy	20,390.00	55.86

Table 3-33 (Cont'd)

VERMILLION RIVER CHUTE CONSTRUCTION PROGRAM

Struc. No.	Type**	Length (ft)	Date Start	Date Finish	Stone (Tons)	L.G.M. (Tons)	Excav. (CY)	Gravel (Tons)	Other	Cost ($)	$/L.F.
769.8* 0+79 to 1+09	HP	30	9/06/77	9/06/77	75	150				2,175.00	72.50
769.8*	HP	86	4/28/77	4/29/77	259		178			4,541.21	52.80
769.75* 0+52 to 1+02	HP	50	9/09/77	9/09/77	125	311				4,204.50	84.09
769.75*	HP	52	4/27/77	4/28/77	117		138			2,080.23	40.00
769.72* 0+10 to 0+40	HP	30	9/07/77	9/07/77	75	175				2,412.50	80.42
769.72*	HP	40	4/29/77	5/2/77	172		150			3,031.68	75.79
769.68*	WRF	50	2/22/77	2/28/77	243		156			4,255.17	85.10
769.65*	WRF	52.2	2/28/77	2/01/77	252		217			4,440.38	85.06
769.62*	WRF	60	3/01/77	3/27/77	253		210			4,454.07	74.23
769.59*	WRF	50	6/21/79	6/22/79	300		225			4,508.75	90.00
769.58*	CR	300	6/27/79	6/29/79		1,406		138		17,663.54	59.00

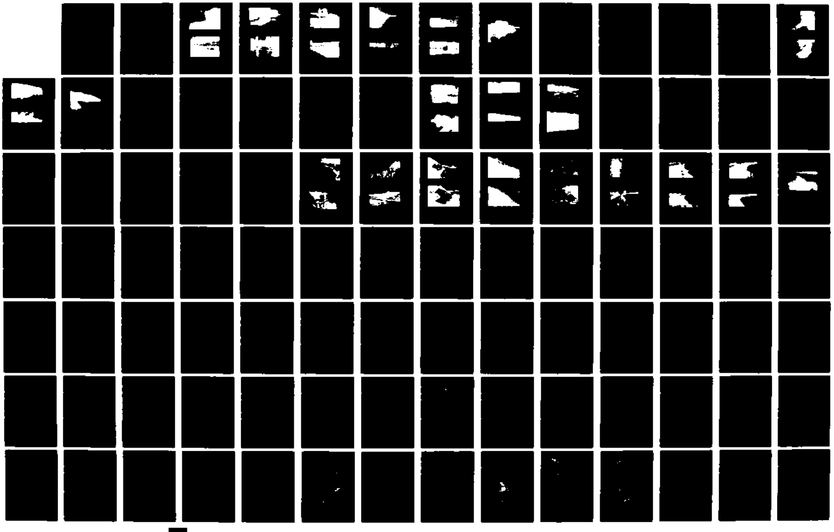
SUBTOTAL	$507,000.00
Seeding	7,000.00
Clearing & Grubbing	10,000.00
Monitoring & Documentation	49,000.00
Supervision & Administration	46,000.00
Engineering & Design	41,000.00
TOTAL COST	$660,000.00

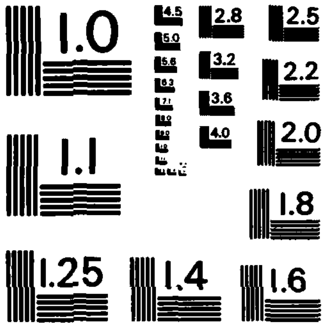
*Designated by 1960 River Mileage

**WRF = Windrow Refusal; CR = Composite Revetment; WR = Windrow Revetment; HP = Hardpoint; RR = Reinforced Revetment

AD-A121 136 THE STREAMBANK EROSION CONTROL EVALUATION AND DEMONSTRATION ACT OF 1974 S..(U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS HYDRA.. 2/4

UNCLASSIFIED M P KEOWN ET AL. DEC 81 F/G 13/2 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Table 3-33a

VERMILLION RIVER CHUTE CONSTRUCTION PROGRAM - REHABILITATION

Struc. No.	Type**	Length (ft)	Date Start	Date Finish	Stone (Tons)	Excav. (CY)	Gravel (Tons)	Cost ($)	$/L.F.
772.01	WRF	35	12/20/79	12/20/79	160	136		2,632.00	75.00
772.00									
0+00 to 5+00	WR	500	10/22/79	1/28/80	2,243	2,028		37,261.70	75.00
5+00 to 10+40	CR	540	10/22/79	1/28/80	1,474			20,488.60	40.00
771.9									
41+70 to 45+45	WR	375	8/22/78	11/03/78	676	847		10,872.61	29.00
50+00 to 52+50	CR	250	7/25/80	7/30/80	712		56	10,694.80	79.00
770.9	WRF	25	1/21/80	1/21/80	106	142		1,899.40	76.00
	WRF	30	7/80	7/80	180	135		2,907.00	97.00
770.1									
27+50 to 29+00	CR	150	7/23/80	7/24/80	468		50	7,217.70	48.00
32+00 to 35+00	CR	300	7/10/80	7/21/80	1,900		140	28,405.00	95.00
36+25 to 36+75	CR	50	7/07/80	7/07/80	300		29	4,583.25	92.00
37+50 to 42+00	CR	450	12/03/79	1/09/80	2,663		139	36,053.65	120.00
39+50 to 40+00	CR	50	7/03/80	7/03/80	450		30	6,682.50	134.00
769.65	WRF	50	7/80	7/80	300	225		4,845.00	97.00

SUBTOTAL	$175,000.00
Clearing & Grubbing	3,000.00
Monitoring	6,500.00
TOTAL COST	$185,000.00

**WRF = Windrow Refusal; CR = Composite Revetment; WR = Windrow Revetment;

PHOTO 49. TYPICAL EROSION ALONG THE VERMILLION RIVER CHUTE AREA THIS PHOTO IS IMMEDIATELY D/S OF THE VERMILLION RIVER (Photo Taken 13 September 1979)

PHOTO 50. TYPICAL COMPOSITE REVETMENT STRUCTURE (Photo Taken 26 October 1977)

PHOTO 51. COMPOSITE REVETMENT 771.9* APPROXIMATELY 11 MONTHS AFTER COMPLETION
(Photo Taken 13 September 1980)

PHOTO 52. HARDPOINT 769.75* APPROXIMATELY 3 MONTHS AFTER COMPLETION
(Photo Taken 2 December 1977)

PHOTO 53. WINDROW REVETMENT 771.9*, APPROXIMATELY 5 MONTHS AFTER COMPLETION. THE UNPROTECTED AREA ON THE PHOTO IS JUST UPSTREAM OF REFUSAL 771.91
(Photo Taken 26 October 1977)

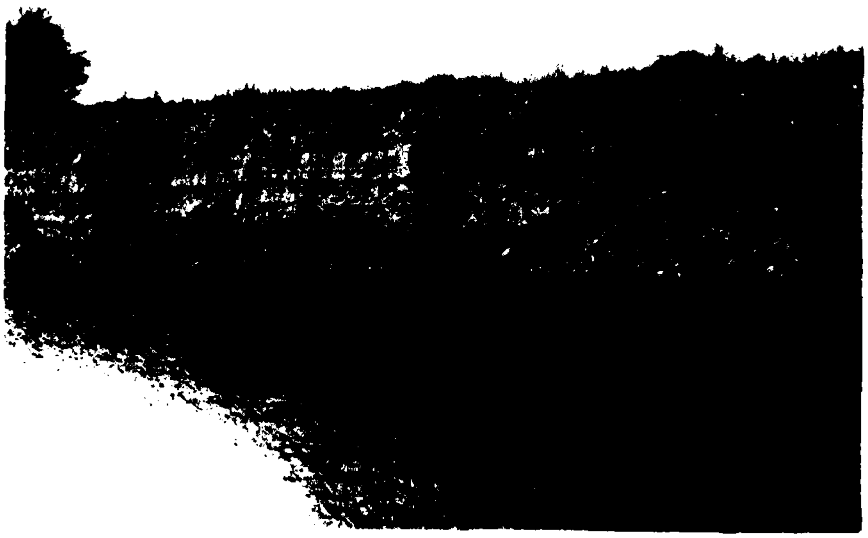


PHOTO 54. WINDROW REVETMENT 771.9*, APPROXIMATELY 5 MONTHS AFTER COMPLETION
(Photo Taken 26 October 1977)

VERMILLION RIVER CHUTE AREA
Photos 53 and 54

PHOTO 55. WINDROW REVETMENT 771.9*, STATION 25+00 APPROXIMATELY
7 MONTHS AFTER COMPLETION
(Photo Taken 2 December 1977)

PHOTO 56. WINDROW REVETMENT 771.9*, APPROXIMATELY 1 YEAR AND
11 MONTHS AFTER COMPLETION
(Photo Taken 17 April 1979)

PHOTO 57. WINDROW REVETMENT 771.9*, APPROXIMATELY 1 YEAR AND 11 MONTHS AFTER COMPLETION. THIS PHOTO SHOWS THE COMPARISON BETWEEN THE STABILIZED BANK AND THE NATURAL BANK CONDITION
(Photo Taken 17 April 1979)

PHOTO 58. WINDROW REVETMENT 771.9*, 2 YEARS AND 4 MONTHS AFTER COMPLETION
(Photo Taken 13 September 1979)

VERMILLION RIVER CHUTE AREA
Photos 57 and 58

PHOTO 59. WINDROW REVETMENT 771.9* IN ITS STABLE CONDITION, 2 YEARS AND 4 MONTHS AFTER COMPLETION. THE STRUCTURE WAS VERY EFFECTIVE IN ESTABLISHING NATURAL VEGETATION GROWTH (Photo Taken 13 September 1979)

8. **RYAN BEND PROJECT AREA**. The general plan for this project is shown on plate 9-1. The initial construction consisted of 3 segments of windrow revetment totalling 1,500 linear feet, 10 windrow refusals totalling 644 linear feet, 4 segments of reinforced revetment totalling 1,880 linear feet, and 3 segments of composite revetment totalling 1,650 linear feet. Extensions to existing structures were added by Modification No. 4. These additions included 315 linear feet of composite revetment and 150 linear feet of windrow revetment. Typical sections of the structure types used in this project are shown on plate 9-2.

Table 3-36 provides a construction program which includes material quantities and costs by structure. Low grade material did display sufficient economic advantage as a bid item for this contract.

Tables 3-34 and 3-35 show the specified gradation requirements for the material utilized in the structures.

Table 3-34

STONE GRADATION A FOR UPPER BANK PAVING, WINDROW REVETMENT AND REFUSALS

Weight per Stone	Percent of Total Weight Lighter than or Passing
200-lbs	100
50-lbs	35-60
2-inch screen	0-15

Table 3-35

STONE GRADATION B (REVETMENT TOE)

Weight per Stone	Percent of Total Weight Lighter than or Passing
500-lbs	100
165-lbs	35-60
3-inch screen	0-15

The stone material was required to meet the following standards: Bulk specific gravity, saturated surface-dry basis Method CRD-C 107-69, required not less than 2.40. Soundness in magnesium sulfate, ASTM Standard C88-73, required a loss of 5 cycles of not more than 12 percent. Soundness in freezing and thawing for ledge rock, Method Modified AASHTO Designation T 103-42, required a loss of 12 cycles of not more than 10 percent.

Stone application rates in average tons per linear foot by structure type for this project site are as follows.

Reinforced Revetment	4.2
Composite Revetment	5.0
Windrow Revetment	5.5
Windrow Refusal	3.9

Photos 60 and 61 display Composite Revetment 768.0, station 12+50 prior to placement of upper bank stone material and after completion. Photographs 62 and 63 show two different views of the same structure, station 0+00, approximately 16 months after completion. Photo 64 displays a typical example of a completed reinforced revetment.

Table 3-36

RYAN BEND CONSTRUCTION PROGRAM

Struc. No.	Type*	Length (ft)	Date Start	Date Finish	Stone (Tons)	L.G.M. (Tons)	Excav. (CY)	Gravel (Tons)	Other	Cost ($)	$/L.F.
768.51	WRF	100	1/24/78	1/31/78	361		302			3,104.90	
768.5 0+30 to 5+50	RR	580	2/06/78	6/29/78							
8+00 to 13+50	RR	550	2/06/78	6/29/78							
17+50 to 21+25	RR	375	2/06/78	6/29/78							
23+60 to 27+35	RR	375	2/06/78	6/29/78	2,595	5,225	698			55,551.35	29.55
768.35	WRF	50	1/12/78	1/12/78	200		243			1,991.60	39.83
768.3	WRF	75	1/14/78	1/14/78	255		329			2,562.30	34.16
768.2	WRF	75	1/19/78	1/19/78	299		307			2,909.90	38.80
768.01	WRF	75	1/23/78	1/24/78	307		347			3,025.90	40.35
768.0 0+00 to 7+50	CR	750	4/07/78	6/29/78	1,311	2,612	2,699			30,707.30	40.94
11+50 to 15+50	CR	400	4/07/78	6/29/78	875	814	1,500			14,325.00	35.81
18+00 to 23+00	CR	500	4/07/78	6/29/78	1,145	1,410	1,800			20,705.00	41.41
767.85	WRF	50	6/15/78	6/15/78	191		357			2,051.90	41.04
767.75	WRF	50	3/01/78	3/01/78	202		192			1,947.40	38.95
767.51	WRF	50	3/29/78	3/29/78	203		341			2,134.70	42.69
767.5 0+00 to 4+00	WR	400	3/07/78	6/29/78							
9+00 to 15+50	WR	600	3/07/78	6/29/78							
21+00 to 27+00	WR	600	3/07/78	6/29/78	3,020	5,166	4,406			63,244.70	42.16

Table 3-36 (Cont'd)

RYAN BEND CONSTRUCTION PROGRAM

Struc. No.	Type*	Length (ft)	Date Start	Date Finish	Stone (Tons)	L.G.M. (Tons)	Excav. (CY)	Gravel (Tons)	Other	Cost ($)	$/L.F.
767.42	WRF	50	3/31/78	3/31/78	211		406			2,280.70	45.61
767.2	WRF	69	6/14/78	6/15/78	307		378			3,063.10	44.39

SUBTOTAL	$220,200.00
Clearing and Grubbing	3,000.00
Seed and Mulching	1,000.00
Monitoring	31,000.00
Sample, Test and Restore	1,000.00
Delete one in-place gradation	-1,000.00
Supervision and Administration	10,000.00
Engineering and Design	20,000.00
TOTAL COST	$285,000.00

*Designated by 1960 River Mileage

**WRF = Windrow Refusal; CR = Composite Revetment; WR = Windrow Revetment, HP = Hardpoint, RR = Reinforced Revetment

PHOTO 60. COMPOSITE REVETMENT 768.0*, STATION 12+50, STONE TOE PRIOR TO PLACEMENT OF UPPER BANK STONE MATERIAL (Photo Taken 23 May 1978)

PHOTO 61. COMPLETED COMPOSITE REVETMENT 768.0*, STATION 12+50 (Photo Taken 29 June 1978)

PHOTO 62. COMPOSITE REVETMENT 768.0*, STATION 0+00
APPROXIMATELY 16 MONTHS AFTER COMPLETION
(Photo Taken 5 October 1979)

PHOTO 63. COMPOSITE REVETMENT 768.0*, STATION 0+00
APPROXIMATELY 16 MONTHS AFTER COMPLETION
(Photo Taken 5 October 1979)

PHOTO 64. REINFORCED REVETMENT 768.5*
APPROXIMATELY 16 MONTHS AFTER COMPLETION
(Photo Taken 5 October 1979)

<u>RYAN BEND AREA</u>
Photo 64

9. **IOWIA BEND PROJECT AREA.** The general plan for this project is shown on plates 10-1 and 10-2. The construction consisted of 7 segments of composite revetment totalling 4,400 linear feet, 5 segments of reinforced revetment totalling 3,000 linear feet, 4 segments of windrow revetment totalling 2,500 linear feet, 13 windrow refusals totalling 725 linear feet, and 2 systems of hardpoints with 6 hardpoints each.

Several types of reinforced revetment are represented at this demonstration site. Reinforced Revetment 759.7, station 31+50 to 35+50 is Type I with a tieback interval of 80 feet. Structure 761.4, station 12+00 to 17+00, and Structure 759.7, stations 10+50 to 18+50 and 22+50 to 28+50 are all Reinforced Revetment Type II with tieback intervals of 50 feet, 100 feet, and 50 feet, respectively. Reinforced Revetment 759.7, station 0+00 to 7+00 is Type III with a tieback interval of 100 feet. A tieback was also constructed at the downstream end on all reinforced revetment segments. All hardpoint roots are Type A with root elevations at 2 feet below existing ground elevation at the landward end of the root. Hardpoint spur elevations are the normal water surface plus 3 feet. No mandatory floating plant construction was required in this contract. Typical sections of the structure types used in this project are shown on plates 10-3 and 10-4.

Table 3-39 provides a construction program which includes material quantities and costs by structure. Low grade material did display sufficient economic advantage as a bid item for this contract.

Tables 3-37 and 3-38 display the specified gradation requirements for the material uitlized in the structures.

Table 3-37

STONE FOR COMPOSITE REVETMENT TOE (UPPER), REINFORCED REVETMENT TIEBACKS, WINDROW REVETMENT AND REFUSALS, HARDPOINT UPPER PAVING FILL AND ROOTS

Weight per Stone	Percent of Total Weight Lighter than or Passing
200-lbs	100
50-lbs	35-60
2-inch screen	0-15

Table 3-38

STONE FOR COMPOSITE REVETMENT TOE (LOWER), REINFORCED REVETMENT TOE, AND HARDPOINT CORE

Weight per Stone	Percent of Total Weight Lighter than or Passing
500-lbs	100
165-lbs	35-60
3-inch screen	0-15

Bulk specific gravity, saturated surface-dry basis, Method CRD-C 107-69, required not less than 2.40. Soundness in magnesium sulfate, ASTM Standard C 88-76, required a loss at 5 cycles of not more than 12 percent. Soundness in freezing and thawing for ledge rock, Method Modified AASHTO Designation T 103-62, required a loss of 12 cycles of not more than 10 percent.

Stone application rates in average tons per linear foot by structure type for this project site are as follows.

Reinforced Revetment	5.7
Composite Revetment	4.3
Windrow Revetment	4.2
Windrow Refusal	6.2
Hardpoints	6.2

Photos 65 and 66 show Composite Revetment 762.1 prior to construction and 2 months after completion. Photos 67 and 68 display examples of composite revetment approximately 1 year after completion. Photo 69 portrays a functioning hardpoint system while photo 70 on this same page demonstrates an actively functioning windrow revetment.

Table 3-39

IONIA BEND CONSTRUCTION PROGRAM

Struc. No.	Type**	Length (ft)	Date Start	Date Finish	Stone (Tons)	L.G.M. (Tons)	Excav. (CY)	Gravel (Tons)	Cost ($)	$/L.F.
762.11*	WRF	75	9/02/78	9/02/78	450		510		7,089.00	94.52
762.1*	CR	1,000	8/28/78	9/26/78	2,027	2,512		418	63,356.49	63.36
761.86*	WRF	75	9/06/78	9/10/78	450		423		6,962.85	92.84
761.85*	CR	850	8/31/78	9/30/78	1,767	2,208	300	323	55,213.29	64.96
761.7*	HP	100	9/05/78	9/20/78	400	253	360	15	9,237.20	92.37
761.65*	HP	100	9/05/78	9/21/78	400	265	182	15	9,113.50	91.14
761.6*	HP	100	9/05/78	9/21/78	379	260	54	15	8,575.50	85.76
761.55*	HP	100	9/06/78	9/23/78	379	257	233	15	8,801.54	88.02
761.5*	HP	100	9/06/78	9/24/78	400	261	545	15	9,595.05	95.95
761.45*	HP	89	9/07/78	9/24/78	400	270	473	15	9,591.45	107.77
761.41*	WRF	50	9/24/78	9/24/78	301		320		4,711.11	94.22
761.4*										
0+00 to 8+00	CR	800	9/07/78	9/29/78	1,771	2,034	1,731	304	55,094.92	68.87
12+00 to 17+00	RR	500	9/07/78	9/29/78	748	2,232	3,000		39,902.68	79.81
761.3*	WRF	50	9/27/78	9/28/78	300		199		4,521.55	90.43
761.25*	HP	100	9/18/78	9/29/78	266	253	250	19	7,250.32	72.50
761.2*	HP	100	9/18/78	9/29/78	266	253	5	19	6,895.07	68.95
761.15*	HP	100	9/19/78	10/02/78	346	252	265	19	8,389.67	83.90
761.1*	HP	100	9/19/78	10/02/78	346	252	243	19	8,357.77	83.58
761.0*	HP	100	9/19/78	10/02/78	346	251	209	19	8,297.27	82.97
760.95*	HP	100	9/20/78	10/02/78	346	253	189	19	8,290.67	82.91
760.91*	WRF	50	10/03/78	10/03/78	300		258		4,607.10	92.14
760.9*										
0+00 to 8+00	WR	800	10/09/78	10/24/78	3,407		4,823		55,066.12	68.83
12+00 to 18+00	WR	600	10/09/78	10/24/78	2,491		3,615		40,389.76	67.32
21+00 to 27+00	WR	600	10/09/78	10/24/78	2,435		3,615		39,599.60	66.00
29+00 to 34+00	WR	500	10/09/78	10/24/78	2,029		3,013		32,998.04	66.00
760.8*	WRF	50	10/12/78	10/12/78	300		167		4,475.15	89.50
760.65*	WRF	50	10/18/78	10/18/78	300		225		4,559.25	91.19
760.5*	WRF	50	10/21/78	10/21/78	283		213		4,301.98	86.04
760.41*	WRF	50	10/24/78	10/24/78	241		176		3,655.71	73.11

Table 3-39 (Cont'd)

IONIA BEND CONSTRUCTION PROGRAM

Struc. No.	Type**	Length (ft)	Date Start	Date Finish	Stone (Tons)	L.G.M. (Tons)	Excav. (CY)	Gravel (Tons)	Cost ($)	$/L.F.
760.4*										
0+00 to 4+00	CR	400	9/20/78	10/31/78	800	1,013	159		25,152.16	62.88
6+00 to 12+00	CR	600	9/20/78	10/31/78	1,200	1,520	242		37,789.28	62.98
760.3*	WRF	50	10/27/78	10/27/78	300		198		4,520.10	90.40
760.2*	CR	700	10/20/78	11/04/78	1,671				23,5[illegible]7.[illegible]	33.68
759.71*	WRF	75	10/28/78	10/28/78	440		207		6,508.55	86.78
759.7*										
0+00 to 7+00	RR	700	9/30/78	11/14/78	595	3,193	3,023	303	53,339.92	76.20
10+50 to 18+50	RR	800	9/30/78	11/14/78	736	3,587	3,454	337	60,905.74	76.13
22+50 to 28+50	RR	600	9/30/78	11/14/78	1,134	2,718	2,591	248	54,127.61	90.21
31+50 to 35+50	RR	400	9/30/78	11/14/78	375	1,797	1,727	38	28,523.72	71.31
759.5*	WRF	50	11/07/78	11/07/78	300		255		4,602.75	92.06
759.3*	WRF	50	11/02/78	11/02/78	300		238		4,578.10	91.56
759.1*	WRF	50	11/02/78	11/02/78	300		234		4,572.30	91.45

SUBTOTAL	$837,000
Clearing and Grubbing	4,000
Seeding	6,000
Monitoring and Documentation	56,000
Engineering and Design	43,000
Supervision and Administration	48,000
TOTAL COST	$994,000

*Designated by 1960 River Mileage

**WRF = Windrow Refusal; CR = Composite Revetment; WR = Windrow Revetment; RR = Reinforced Revetment; HP = Hardpoint

PHOTO 65. SITE OF COMPOSITE REVETMENT 762.1*, LOOKING D/S
PRIOR TO CONSTRUCTION
(Photo Taken 6 August 1978)

PHOTO 66. COMPLETED COMPOSITE REVETMENT 762.1*, LOOKING D/S
2 MONTHS AFTER COMPLETION
(Photo Taken 8 November 1978)

PHOTO 67. COMPOSITE REVETMENT 762.1*, LOOKING U/S APPROXIMATELY 1 YEAR AFTER STRUCTURE COMPLETION (Photo Taken 5 October 1979)

PHOTO 68. COMPOSITE REVETMENT 761.85*, LOOKING U/S APPROXIMATELY 1 YEAR AFTER STRUCTURE COMPLETION (Photo Taken 5 October 1979)

PHOTO 69. COMPLETED HARDPOINTS 761.55*, 761.6*, 761.65*, 761.7*
LOOKING U/S, APPROXIMATELY 1 YEAR AFTER COMPLETION
(Photo Taken 5 October 1979)

PHOTO 70. WINDROW REVETMENT 760.9*, LOOKING U/S
ACTIVELY FUNCTIONING APPROXIMATELY 1 YEAR AFTER COMPLETION
(Photo Taken 5 October 1979)

10. **ELK POINT (PHASE I AND II) PROJECT AREA**. The general plan for this project is shown on plates 11-1 and 11-2. The combined construction at this demonstration site consisted of 13 segments of composite revetment totalling 5,085 linear feet, 4 segments of reinforced revetment totalling 1,700 linear feet, 5 segments of windrow revetment totalling 4,850, 18 windrow refusals, and 3 hardpoint systems consisting of 2, 5, and 6 hardpoints, respectively.

Table 3-40 denotes types of composite revetment that were demonstrated at the Elk Point Area. Typical sections of these types are found on plates 11-4 and 11-5.

Table 3-40

TYPES OF COMPOSITE REVETMENT USED AT ELK POINT

Structure No.	Station	Type
756.28	0+00 to 4+00	F
755.7	0+00 to 7+00	F
755.25	0+00 to 4+00	F
755.25	7+00 to 13+75	F
754.77	0+00 to 5+00	F
754.77	7+00 to 9+50	F
754.77	11+50 to 13+00	K
754.77	13+00 to 14+50	L
754.77	16+00 to 17+50	H
754.77	17+50 to 19+00	J
754.77	20+50 to 23+50	G
753.67	0+00 to 5+00	F
753.66	8+00 to 14+00	E

The reinforced revetment used at Elk Point are of two types. Type I and Type II as depicted in the typical section on plate 11-3. Table 3-41 categorizes the structures by type.

Table 3-41

Structure No.	Station	Type
756.65	3+50 to 8+00	II
756.18	0+00 to 6+50	I
755.55	0+00 to 5+00	I
754.3	0+00 to 6+00	II
754.3	9+00 to 15+00	I

All reinforced revetments have tieback intervals of 100 feet. Tiebacks were also constructed at the downstream end of all reinforced revetment segments.

There are three systems of hardpoints in the Elk Point Project Area. The system farthest upstream in this project area consists of only two hardpoints. Hardpoint 756.51 is Type I and Hardpoint 756.56 is Type II and the only one of its kind in the entire Gavins Point to Ponca reach. Type II hardpoints consist of only two (2) components: (1) a spur core of stone or low grade material extending from the bank into the river, and (2) an upper paving fill of stone placed on top of the spur core. Therefore, this hardpoint has no root and the landward end of the hardpoint spur core begins as close to the high bank as possible. The spacing interval between Hardpoint 756.56 and 756.51 is approximately 264 feet.

The second system consists of 5 hardpoints which are all Type I with Type A roots. These hardpoints were all spaced at intervals of approximately 264 feet. The last system of hardpoints consists of 6 structures of which all are Type I with Type A roots. The spacing of these hardpoints is approximately 158 feet. The alignment of these

structures was changed in the field to give the structures more of an angle with the flow of the river. Typical sections of hardpoints are depicted on plate 11-4.

The last structure category to be discussed in this project area is windrow revetment. All windrow revetments are Type A as shown on plate 11-4.

No mandatory floating plant construction was required in this project area. Tables 3-44 through 3-46 provide construction programs which include material quantities and costs by structure. Low grade material did not display sufficient economic advantage as a bid item for this contract; therefore, all structures in this project were constructed of durable stone. Tables 3-42 and 3-43 display the specified gradation requirements for the material utilized in the structures.

Table 3-42

STONE FOR COMPOSITE REVETMENT TOE, TYPE F (UPPER) COMPOSITE REVETMENT TOE, TYPE E (UPPER), REINFORCED REVETMENT TIEBACKS, WINDROW REVETMENT AND REFUSALS, HARDPOINT UPPER PAVING FILL TYPES I AND II AND ROOT TYPE A

Weight per Stone	Percent of Total Weight Lighter than or Passing
200-lbs	100
50-lbs	35-60
2-inch screen	0-15

Table 3-43

STONE FOR COMPOSITE REVETMENT TOE, TYPE F (LOWER), COMPOSITE REVETMENT TOE, TYPE E (LOWER), G, H, J, K, L, REINFORCED REVETMENT TOE, AND HARDPOINT TYPES I AND II CORE

Weight per Stone	Percent of Total Weight Lighter than or Passing
500-lbs	100
165-lbs	35-60
3-inch screen	0-15

Bulk specifc gravity, saturated-dry basis Method CRD-C 107-69, required not less than 2.40. Soundness in magnesium sulfate, ASTM Standard C88-76, required a loss at 5 cycles of not more than 12 percent. Soundness in freezing and thawing for ledge rock, Method Modified AASHTO Designation T 103-62, required a loss at 12 cycles of not more than 10 percent.

Stone application rates in average tons per linear foot by structure type are as follows.

Elk Point Phase I

Composite Revetment	5.0
Windrow Revetment	5.5
Windrow Refusal	5.8
Hardpoints	5.8

Elk Point Phase II

Reinforced Revetment	5.4
Composite Revetment	4.5
Windrow Revetment	4.5
Windrow Refusal	6.0
Hardpoints	6.8

Photos 71 through 87 show various examples of structures constructed in the Elk Point Project Area. Where possible, photographs were used which depicted the site of a specific structure before construction and again after completion. In some instances, as for Windrow Revetment 756.05 and Composite Revetment 754.77 (Photos 71 through 78), sequential steps of construction are shown.

Table 3-44

ELK POINT-PHASE I CONSTRUCTION PROGRAM

Struc. No.	Type**	Length (ft)	Date Start	Date Finish	Stone (Tons)	Gravel (Tons)	Excav. (CY)	Cell.Blks Ero.Fab.Sys.	Cost ($)	$/L.F.
756.06*	WRF	100	9/04/79	9/12/78	600		467		9,800.70	98.01
756.05										
0+00 to 4+00	WR	400	9/08/79	10/01/79	1,800		2,469		31,645.00	79.00
7+00 to 12+50	WR	550	9/08/79	10/01/79	2,529		3,446		44,413.00	81.00
755.81*	WRF	50	9/10/79	10/03/79	300		234		4,901.40	98.03
755.71*	WRF	50	9/01/79	10/03/79	300		233		4,899.30	97.90
755.70										
0+00 to 9+66	CR	966	10/03/79	2/26/80	4,736	606			77,739.60	80.5
10+00 to 19+85	WR	985	10/03/79	2/26/80	5,014		7,505		89,466.30	45.00
755.41*	WRF	135	12/21/79	6/01/79	669		628		11,153.10	82.62
755.4*	WR	1,015	12/13/79	1/08/80	4,568		6,504		80,808.00	79.50
755.26*	WRF	50.	2/23/80	2/23/80	306		231		4,983.30	99.67
755.25										
0+00 to 4+00	CR	400	2/20/80	3/11/80	1,800	242			29,702.80	74.00
6+00 to 12+75	CR	675	2/20/80	3/11/80	3,081	423			50,958.90	75.5
755.13*	WRF	50	2/19/80	2/19/80	312		231		5,071.50	101.43
754.96*	HP	80	2/09/80	2/09/80	491	26	317		8,231.80	102.90
754.93*	HP	80	2/08/80	2/08/80	482	26	325		8,116.30	101.45
754.90*	HP	80	2/07/80	2/07/80	451	26	335		7,681.60	96.02
754.87*	HP	80	2/06/80	2/06/80	454	26	321		7,696.30	96.20
754.84*	HP	80	2/05/80	2/05/80	461	27	310		7,789.50	97.37
754.81*	HP	80	1/28/80	1/30/80	450	20	300		7,513.00	93.91
754.78*	WRF	50	1/22/80	1/22/80	300		233		4,899.30	97.99
754.77	CR		12/13/79	6/03/80	7,724	705	3,651	1,495 / 1,450	166,221.90	100.74
0+00 to 5+00		500								
7+00 to 9+50		250								
11+50 to 14+50		300								
16+00 to 19+00		300								
20+50 to 23+50		350								

Table 3-44 (Cont'd)

ELK POINT-PHASE I CONSTRUCTION PROGRAM

Struc. No.	Type**	Length (ft)	Date Start	Date Finish	Stone (Tons)	Gravel (Tons)	Excav. (CY)	Cell.Blks Ero.Fab.Sys.	Cost ($)	$/L.F.
754.65*	WRF	40	1/21/80	1/21/80	240		187		3,920.70	98.02
754.55*	WRF	40	1/17/80	1/17/80	240		187		3,920.70	98.02
754.45*	WRF	40	1/18/80	1/18/80	240		187		3,920.70	98.02
754.38*	WRF	40	1/19/80	1/19/80	240		187		3,920.70	98.02
754.31*	WRF	40	1/19/80	1/19/80	240		187		3,920.70	98.02
754.30*	CR	600	5/02/80	6/03/80	3,435	356	2,060		59,590.90	99.32

SUBTOTAL	$741,500
Clearing and Grubbing	9,000
Seeding	5,100
Monitoring and Evaluation	54,000
Supervision and Administration	30,000
Engineering and Design	30,000
TOTAL COST	$870,000

*Designated by 1960 River Mileage

**WRF = Windrow Refusal; WR = Windrow Revetment; CR = Composite Revetment; RR = Reinforced Revetment

Table 3-45

ELK POINT-PHASE I CONSTRUCTION PROGRAM (RECONSTRUCTION)

Struc. No.	Type**	Length (ft)	Date Start	Date Finish	Stone (Tons)	Excav. (CY)	Gravel (Tons)	Cell.Blks Ero.Fab.Sys.	Cost ($)	$/L.F.
755.7 4+00 to 9+66	CR	566	10/03/79	6/03/80	902		356		18,029.80	32.00
755.4 -3+00 to 1+00	WR	400	12/13/79	5/31/80	998	2,064			19,005.00	47.50
755.41 -0+35 to 0+00	WRF	35	12/21/79	6/1/80	69	158			1,346.1	38.5

SUBTOTAL	$38,400
Supervision and Administration	3,000
Engineering and Design	4,000
	$45,000

Table 3-46

ELK POINT-PHASE II CONSTRUCTION PROGRAM

Struc. No.	Type**	Length (ft)	Date Start	Date Finish	Stone (Tons)	Excav. (CY)	Gravel (Tons)	Cost ($)	$/L.F.
756.65*	RR	450	7/17/80	8/18/80	2,250	980	225	30,614.25	68.03
756.56*	HP	52	7/14/80	8/06/80	375		30	5,415.75	104.15
756.51*	HP	100	7/31/80	8/05/80	658	299	30	8,604.20	86.04
756.47*	WRF	50	7/03/80	7/03/80	300	225		4,920.00	98.40
756.46*	WR	900	6/23/80	7/03/80	4,050	5,800		68,077.50	75.64
756.29*	WRF	50	6/13/80	6/20/80	300	225		4,920.00	98.40
756.28*	CR	400	6/04/80	6/19/80	1,800		240	31,098.00	77.75
756.19*	WRF	50	5/21/80	5/21/80	306	230		5,018.70	100.37
756.18*	RR	650	5/13/80	6/17/80	3,585	2,020	390	62,273.25	95.81
754.30*	RR	600	6/27/80	8/18/80	3,360	1,810	410	58,757.50	97.93
754.13*	WRF	50	6/26/80	6/27/80	300	225		4,920.00	98.40
753.90*	HP	100	8/19/80	8/28/80	602	300	25	7,863.45	78.63
753.85*	HP	100	3/14/80	8/28/80	602	302	25	7,864.65	78.65
753.80*	HP	90	8/13/80	8/28/80	602	305	13	7,747.05	86.08
753.75*	HP	80	8/08/80	8/28/80	599	315	12	7,706.05	96.33
753.70*	HP	80	8/07/80	8/28/80	600	320	10	7,701.50	96.27
753.67*	WRF	50	6/06/80	6/06/80	300	225		4,920.00	98.40
753.66									
0+00 to 5+00	CR	500	6/09/80	8/25/80	2,250		216	38,036.70	16.90
8+00 to 16+60	CR	860	5/02/80	8/21/80	3,870		480	66,502.50	17.18
753.55*	WRF	50	5/01/80	5/01/80	300	224		4,919.40	98.39

SUBTOTAL	$437,880
Clearing and Grubbing	1,000
Seeding	3,000
Monitoring and Evaluation	14,000
Supervision and Administration	23,000
Engineering and Design	16,000
TOTAL COST	$495,000

*Designated by 1960 River Mileage

**RR = Reinforced Revetment; HP = Hardpoint; WRF - Windrow Refusal; WR = Windrow Revetment; CR = Composite Revetment

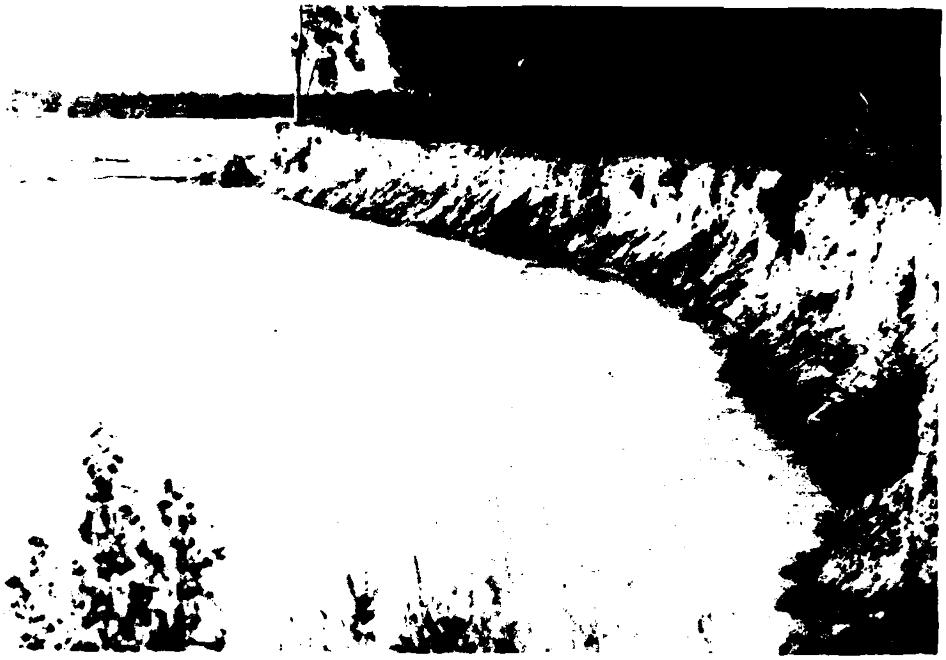


PHOTO 71. SITE OF TYPE A WINDROW REVETMENT 756.05* PRIOR TO CONSTRUCTION, LOOKING U/S (Photo Taken 11 September 1979)

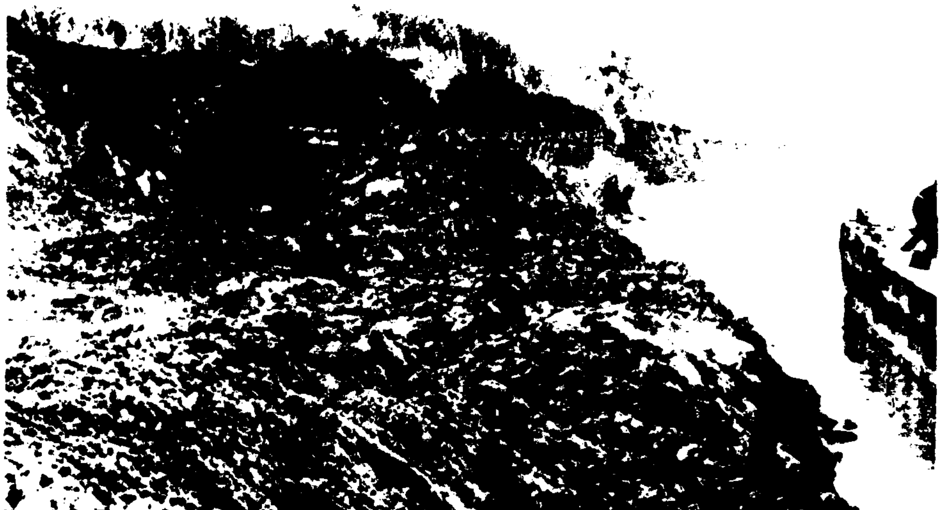


PHOTO 72. WINDROW REVETMENT 756.05* TYPE A, AFTER EXCAVATION, LOOKING D/S (Photo Taken 13 September 1979)

PHOTO 73. WINDROW REVETMENT 756.05* TYPE A DURING PLACEMENT OF STONE
(Photo Taken 17 September 1979)

PHOTO 74. WINDROW REVETMENT 756.05* DURING PLACEMENT OF EARTH COVER
(Photo Taken 18 September 1979)

PHOTO 75. SITE OF COMPOSITE REVETMENT 754.77*
PRIOR TO CONSTRUCTION, LOOKING D/S
(Photo Taken 15 September 1979)

PHOTO 76. COMPOSITE REVETMENT 754.77* DURING PLACEMENT OF HOLD/GRO FABRIC, AND PRIOR TO PLACEMENT OF CELLULAR CONCRETE BLOCKS, LOOKING D/S
(Photo Taken 19 March 1980)

PHOTO 77. COMPOSITE REVETMENT 754.77* AFTER THE CELLULAR CONCRETE BLOCKS WERE PLACED OVER FILTER CLOTH TO PROVIDE UPPER BANK TREATMENT, LOOKING D/S
(Photo Taken 28 March 1980)

PHOTO 78. COMPLETED COMPOSITE REVETMENT 754.77* IMMEDIATELY AFTER GRAVEL PLACEMENT OVER THE CELLULAR CONCRETE BLOCKS
(Photo Taken 3 April 1980)

ELK POINT PHASE I
Photos 77 and 78

PHOTO 79. COMPOSITE REVETMENT 754.05* SHOWS MINOR DAMAGE TO UPPER BANK PROTECTIONS CAUSED BY NATURAL RUNOFF, WAVE WASH, AND LEACHING
(Photo Taken 5 September 1980)

PHOTO 80. COMPOSITE REVETMENT 754.05* SHOWS CONSIDERABLE DAMAGE TO THE UPPER BANK CELLULAR CONCRETE BLOCK PROTECTION CAUSED BY NATURAL RUNOFF, WAVE WASH, AND LEACHING
(Photo Taken 5 September 1980)

PHOTO 81. SITE OF COMPOSITE REVETMENT 753.66*, TYPE E, STATION 8+00
PRIOR TO CONSTRUCTION, LOOKING D/S
(Photo Taken 30 May 1980)

PHOTO 82. COMPOSITE REVETMENT 753.66*, TYPE E, STATION 8+00
THREE WEEKS AFTER COMPLETION, LOOKING D/S
(Photo Taken 8 August 1980)

PHOTO 83. SITE OF COMPOSITE REVETMENT 756.28*, TYPE F
PRIOR TO CONSTRUCTION
(Photo Taken 28 May 1980)

PHOTO 84. COMPOSITE REVETMENT 756.28*, TYPE F
APPROXIMATELY 2 MONTHS AFTER COMPLETION
(Photo Taken 8 August 1980)

PHOTO 85. SITE OF WINDROW REVETMENT 756.46*, TYPE A PRIOR TO CONSTRUCTION, LOOKING U/S (Photo Taken 18 June 1980)

PHOTO 86. WINDROW REVETMENT 756.46*, TYPE A PHOTO SHOWS STRUCTURE APPROXIMATELY 1 MONTH AFTER COMPLETION. LOOKING U/S (Photo Taken 8 August 1980)

PHOTO 87. REINFORCED REVETMENT 754.3*, TYPE I
LOOKING D/S IMMEDIATELY AFTER COMPLETION
(Photo Taken 8 August 1980)

ELK POINT II AREA
Photo 87

11. **MULBERRY POINT.** The Mulberry Point project was designed to demonstrate the use of Reef Stabilizers, Flow Control Stabilizers and Composite Revetment as shown on the general plan Plate 6-1. The typical sections for these structures are shown on Plates 6-2 and 6-3. This contract was awarded in September 1977, however, the inability of the project sponsor to obtain the necessary construction easement rights-of-way required the contract to be terminated. The total cost for the project including engineering and design, supervision and administration, monitoring costs and costs to the contractor as a result of termination totalled $85,000.

IV - PERFORMANCE OF PROTECTION

A. MONITORING PROGRAM

The monitoring programs for all projects in this reach contained the following common items: bankline location surveys; overbank/streambank cross sections; velocity measurements; controlled aerial photography; ground level photographs; and qualitative structural changes. The site specific monitoring data obtained for each site is discussed in paragraph 3, SITE SPECIFIC MONITORING, of this section.

A lump sum bid item, "Monitoring and Documentation", was included in the construction contracts and consisted of special cross sections and photography taken before, during and after construction.

1. **CROSS SECTIONS.**

a. Cross sections were obtained at the intervals described below for each structure type where applicable at the following listed demonstration sites:

Brooky Bottom Road Area
Vermillion River Chute Area

(1) **Hardpoints:** Root sections, 25 feet or less (three minimum) oriented perpendicular to the root alignment; and one following the structure alignment or center line from the landward end of the root and extending riverward past the terminus.

(2) **Composite and Windrow Revetment:** 50 feet or less, oriented perpendicular to the refusal alignment.

(5) **Refusals:** 50 feet or less, oriented perpendicular to the refusal alignment.

b. Cross sections were obtained at the intervals described below for each structure type where applicable at the following listed demonstration sites:

Mulberry Bend

Ryan Bend

(1) **Composite Revetment and Windrow Revetment:** 200 feet or less, with a minimum of one section at the upstream and downstream end, and the midpoint of any segment ordered on the Construction Schedule.

(2) **Stone Root:** One oriented along the root alignment; and two located at the third points, oriented perpendicular to the root.

(3) **Vane Dikes:** One section along the structure alignment and three sections perpendicular to the structure alignment (with one at each end and one at the midpoint).

(4) **Reinforced Revetment:** Along the centerline of each tieback, approximately perpendicular to the bank.

(5) **Refusals:** One oriented along the refusal alignment and one located at the midpoint, oriented perpendicular to the refusal alignment.

c. Cross sections are obtained at the intervals described below for each structure type where applicable at the following listed demonstration sites:

Goat Island
Ionia Bend
Vermillion Boat Club

(1) **Hardpoints**: Root sections, 25 feet or less (two minimum) oriented perpendicular to the root alignment; and one following the structure alignment or centerline from the landward end of the root and extending riverward past the terminus of the hardpoint spur.

(2) **Reinforced Revetment**: 200 feet or less oriented perpendicular to the structure alignment; and a minimum of one section at the upstream and downsteam ends and the midpoint of any segment ordered on the Construction Schedule.

(3) **Windrow Revetments**: 200 feet, oriented perpendicular to the structure alignment.

(4) **Windrow Refusals**: One oriented along the refusal alignment; and two located at the third point, oriented perpendicular to the refusal.

(5) **Composite Revetment**: 200 feet or less perpendicular to the riverbank; and a minimum of one section at the upstream and downstream ends and the midpoint of any segment ordered on the Construction Schedule oriented.

d. Cross sections were obtained at the intervals described below for each structure type where applicable at the following listed demonstration sites:

Elk Point (Phase I)
Elk Point (Phase II)
Cedar County Park (Phase I)
Cedar County Park (Phase II)

(1) **Hardpoints:** One section following the structure alignment or centerline from the landward end of the structure and extending riverward past the terminus of the hardpoint spur.

(2) **Reinforced Revetment:** 200 feet or less oriented perpendicular to the structure alignment; and a minimum of one section at the upstream and downstream ends and the midpoint of any segment ordered on the Construction Schedule. Each cross section shall coincide with the centerline of the nearest tie-back consistent with the above criteria.

(3) **Windrow Revetment:** 200 feet or less and a minimum of one section at the upstream and downstream ends and the midpoint of any segment ordered on the Construction Schedule. Each section is oriented perpendicular to the structure alignment.

(4) **Composite Revetment:** 200 feet or less and a minimum of one section at the upstream and downstream ends and the midpoint of any segment ordered on the Construction Schedule. Each section is oriented to the structure alignment.

(5) **Windrow Refusals:** One section oriented along the refusal centerline.

(6) **Inter-Structure Gaps:** 200 feet or less and a minimum of one section located at the midpoint of the gap. Each section is oriented approximately perpendicular to the flow.

2. PHOTOGRAPHY

a. Photography requirements as described below were required at the following listed demonstration sites:

Brooky Bottom Road

Ionia Bend

Goat Island

Vermillion River Chute

(1) **Reinforced Revetment:** Photographs were obtained of the upstream end and at 500 foot intervals for each revetment segment longer than 1,000 feet. For revetment segments between 1,000 and 500 feet or less in length, photographs were obtained for the upstream end and at the mid-point of the segment. For revetment segments 500 feet or less in length, photographs were obtained at the upstream end, and all photographs shall be oriented in the downstream direction. The photographs were taken prior to any construction; then prior to application of the bank zone treatments; and then after structure completion. The same vantage point was used for each series of photos.

(2) **Composite and Windrow Revetments:** Photographs were obtained at the upstream end at 500 foot intervals for each revetment segment longer than 1,000 feet. For revetment segments less than 1,000 feet in length, photographs were obtained for the upstream end and at the mid-point of the segment. All photographs were oriented in the downstream direction. The photographs were taken prior to any clearing, excavation, stone placement and backfilling; and after backfilling and grading. The same vantage point was used for each series of photos.

(3) **Hardpoints:** Photographs were obtained at each hardpoint location. The photographs include the bankline prior to construction; the completed structure, taken along the structure azimuth line; and the structure and downstream bankline, taken parallel to the bankline.

(4) **Material Acquisition Sites:** Same for all Sec. 32.

b. Photography requirements as described below were required at the following demonstration sites:

Ryan Bend

Vermillion Boat Club

(1) **Material Acquisition Sites:** Photographs were obtained of the rock and gravel when stockpiled for each gradation test, at the

quarry site and the job site. The photographs provide sufficient detail to permit differentiation of the individual particles. The field of view includes a 1-foot (minimum) interval of a rod, graduated to tenths-of-feet or smaller, for dimensional reference.

(2) **Composite Revetment:** Photographs were obtained of the upstream and downstream ends at 300-foot intervals for each revetment segment longer than 1,000 feet. For revetment segments less than 1,000 feet in length, photographs were obtained for the upstream and downstream ends and at the mid-point of the segment. All photographs, except at the downstream end, are oriented in the downstream direction; and at the downstream end, they are oriented upstream. The photographs were taken prior to any clearing, excavation, stone placement and backfilling; and after backfilling and grading. The same vantage point was used for each series of photos.

(3) **Hardpoints:** Photographs were obtained at each hardpoint location. The photographs include the bankline prior to construction; the root trench after excavation; the completed structure, taken along the structure azimuth line; and the structure and downstream bankline, taken parallel to the bankline.

c. Photography requirements as described below were required at the following listed demonstration sites:

Mulberry Bend
Elk Point (Phase I)
Elk Point (Phase II)
Cedar County Park (Phase I)
Cedar County Park (Phase II)

(1) **Material Acquisition Sites:** Photographs were obtained of the rock and gravel when stockpiled for each gradation test, at the quarry site and the job site. The photographs provide sufficient detail to permit differentiation of the individual particles. The field of view

includes a 1-foot (minimum) interval of a rod, graduated to tenths-of-feet or smaller, for dimensional reference.

(2) **Revetments**: Each revetment segment was photographed taken from a station 100 feet upstream from the upstream end of the segment. Also, photographs were obtained at the upstream end and at 500-foot intervals for each revetment segment longer than 1,000 feet. For revetment segments between 1,000 and 500 feet in length, photographs were obtained at the upstream end and at the mid-point of the segment. For revetment segments 500 feet or less in length, photographs were obtained at the upstream end. The photographs were taken prior to any construction and after structure completion. The same vantage point was used for each pair of photos and all photos were obtained in the downstream direction.

(3) **Hardpoints**: Photographs were obtained at each hardpoint location. The photographs include the bankline prior to construction; the completed structure, taken along the structure azimuth line; the structure and downstream bankline, taken parallel to the bankline; and the structure and upstream bankline, taken parallel to the bankline.

(4) **Vane Dikes (Mulberry Bend only)**: Photographs were obtained for each vane dike and include 4 photographs taken along the structure azimuth line in a landward to riverward direction; prior to and during stone placement, just prior to the crown degradation operation, and 45 days or more after structure completion.

3. SITE SPECIFIC MONITORING

B. EVALUATION OF PROTECTION

1. CEDAR COUNTY PARK (PHASE I) PROJECT AREA.

a. **Detailed Channel Characteristics**. (See Plate 1-1 for Range locations)

(1) **Range 33A.3 through 30.1.** The upstream half of this portion of the project area contains only a narrow chute (50 to 100 feet) running adjacent to the bankline with very low velocity flows. The lower half of this area contains shallow water depths (4 to 6 feet) with fairly high velocities concentrated along the bank. The present underwater bank slopes are stable at slopes of approximately 1V on 5H.

(2) **Range 30.1 through 28A.** Near channel conditions in this portion of the bankline is characterized by deep channels (7 to 16 feet) with low velocities within 25 feet of water's edge. The underwater slope between the hardpoints varies from 1V on 3H to 1V on 4H. The underwater slope along Composite Revetment 799.15, station 0+00 to 4+00 varies from 1V on 2H to 1V on 3.5H.

(3) **Range 28A through 21L.** This portion of the project area is composed of two segments of composite revetment. This area is characterized by a very irregular channel bottom with channel depths within 25 feet of water's edge ranging from 3 to 12 feet. The underwater bank slopes in the area range between a very stable slope of 1V on 10H to a very unstable slope of 1V on 2H with the average slope approximately 1V on 4H. Stream velocities along this portion of the project are very low along the bank.

(4) **Range 21L through 21.** This portion of the project is characterized by uniform channel depths (9 feet) and high velocities immediately adjacent to the structures. The underwater slope is approximately 1V on 2.5H but should flatten out as the structures stabilize the bankline.

b. **Significant Observations.** Until the sandbar located upstream of the project migrates downstream, Reinforced Revetment 799.64 will not be adequately tested for effectiveness. All structures at the Cedar County Park - Phase I Area remain structurally sound and have

eliminated the severe erosion in the area. Hydrographic soundings and velocities have only been obtained immediately after project completion and therefore the present detailed channel conditions are unknown but visual site evaluations indicate the entire project is in a very stable condition.

c. **Recommendations.** None of the structures at this area have suffered any damage in the year and one-half since completion. However, high flows have not been experienced since completion and therefore recommendations on tieback spacing cannot be made. The windrow revetment segment is just beginning to function in which the 4.5 tons per linear foot of stone should be adequate to reach an equilibrium situation. The composite revetment segments are composed of low grade material in the lower toe zone which has not broken down to date and hopefully will be an adequate replacement for stone in the below water zones. The unprotected spacing between structures range from 200 to 300 feet between revetments and 200 feet between hardpoints. These spacing intervals are functioning very well in keeping the gap erosion to a minimum and is recommended for other areas with similar flow conditions.

2. CEDAR COUNTY PARK (PHASE II) PROJECT AREA.

a. **Detailed Channel Characteristics.** (See Plate 2-1 for Range locations)

(1) **Range 20A through 18.1.** Channel depths along this fairly uniform channel bottom range from 9 feet to 17 feet within 25 feet of water's edge. The underwater slope is approximately 1V on 2H over most of this segment with high velocities up to 3 ft/sec concentrated along the bank.

(2) **Range 18A through 16.** This bankline area is protected by 7 hardpoints. The bed character in September 1980, three months after project completion, was very irregular with channel depths within 25 feet of water's edge ranging from one to seven feet.

b. Significant Observations. The structures in the Phase II area were not completed until June 1980 and have not experienced any high flows so they may be properly tested. A new variation of Reinforced Revetment has been constructed at this area which has no backfill behind the stone toe placed approximately 40 feet riverward of the high bank. The hardpoints are similar to previously demonstrated hardpoints at spacing intervals ranging from 150 to 300 feet.

c. Recommendations. The structures have not been in place long enough to adequately evaluate their effectiveness.

3. GOAT ISLAND PROJECT AREA.

a. Detailed Channel Characteristics. Along the upstream 1/2 of the project length, where the bankline alignment was irregular and the revetment structures follow this irregular shape, the efficiency of the flow (streamlining) did not significantly improve. Whereas, the downstream 1/2 of the project, which had a smooth bankline character, has developed a more efficient flow condition by the streamlining of flow. In addition, field data indicates less flow turbulence, a smoother river bed boundary and more uniform sediment movement.

The percentage of protected bankline averages 70 percent, but was generally 600-foot revetment segments with a 300-foot length of unprotected bankline between revetment segments. The unprotected bankline segments have not significantly eroded since project construction completion in late 1978. However, the main flow has remained divided along this river reach between the right and left banks and therefore the general structure scheme has not been tested under sustained high concentrated flow conditions.

Near the central portion of the project area, five hardpoint structures were installed along a very slight convex shaped bankline. The

unprotected areas between individual hardpoints, spaced at 200-foot intervals, have accumulated sediment to reduce depths by more than 50 percent and there has not been any noticable erosion between structures, which has occurred on other hardpoint systems installed at longer spacing intervals.

The underwater slope along the reinforced revetment in this project area, 25 feet out from the water's edge, became more uniform following construction and also became flatter (average slope prior to construction was 1 vertical on 3.85 horizontal and after construction was 1 vertical on 4.25 horizontal).

In the downstream portion of the project area where three composite revetment segments are constructed, the underwater slope averages 1 vertical on 1.9 horizontal and is flatter than the natural angle of repose for stone fill material. This area does have concentrated flow conditions as it is downstream from the split flow area. Because the 25-foot sounding is probably riverward of the structure toe stone, the present slope of structure underwater face is not actually known but the field data that was measured at the 25-foot distance does indicate a better underwater bank stability at time of survey than before construction conditions.

b. **Significant Observations**. Overall, all structures at the Goat Island Project Area have functioned exceptionally well and have not experienced any damage.

Construction of the riverward toe crown elevation of reinforced revetment at Normal Water Surface, with the landward toe crown elevation 2 feet above NWS appears to be higher than necessary due to the existence of intermittent tiebacks. The various tieback spacings have not been adequately tested.

The three windrow revetment segments are still in the process of feeding into the river and have not yet reached a stable condition.

The hardpoint system composed of five individual hardpoints have functioned very well.

c. **Recommendations.** The crown elevation of the reinforced revetment segments could be lowered two feet and still remain effective. A recommendation on tieback spacing cannot be made because they have not been adequately tested.

The unprotected gaps between the structure have not been exposed to direct attack due to split channel flows and therefore the recommendation on spacing size cannot be made.

4. VERMILLION BOAT CLUB PROJECT AREA.

a. **Detailed Channel Characteristics.** (see Plate 4-1 for Range locations)

(1) **Range 0 through 4.** Very little change in water depth and velocity occurred in the near bank area (within 25 feet of water's edge). The cross section area from water's edge to 75 feet out did progressively increase in area but not an equal increase in average velocity. The bed character remained irregular with depths ranging from 2 to 12 in October 1977 to 5 to 12 feet in September 1980.

(2) **Range 5 through 13.** Channel depths along the near bank increased from 1977 to 1978 and then changed very little since the hardpoints were constructed. The cross section area for 75 feet out from water's edge was almost unchanged from 1977 to 1978 and then decreased from 1978 to 1980 to generally a little less than the 1977 values. Some shoaling is developing between hardpoints in the area near the end of each hardpoint structure. Bed character changed from irregular to smoother to irregular between 1977 and 1980. Also, in September 1980, the higher velocities were more concentrated along the bank than they were in 1977.

(3) **Range 14 through 16.** Channel depths decreased slightly from 1977 to 1978 and following construction of three hardpoints the depths doubled along with an increase in the channel irregularity. In October 1977, the underwater bank slope was uniform at about 1V on 6H, but by September 1978 the slope became irregular ranging from 1V on 3H to 1V on 6H. By September 1980, the slope became even more irregular ranging from 1V on 3H to 1V on 8H.

(4) **Range 17 through 22.** This left channel is again split by a long sandbar which further divides and concentrates the flows. The area within 75 feet of the bankline had an increase in depth from 1977 to 1978 and a decrease in depth from 1978 to 1980 to near the 1977 values. The underwater bank slope has remained about 1V on 5H since 1977.

(5) **Range 23 through 29.** The higher velocity flows remained riverward from this bankline segment during the period 1977 through 1980 and there are small sandbars and shoals near the bank. There has been very little change in water depths and flow velocities along this bankline segment; therefore, the structures have not been significantly tested through 1980.

(6) **Range 29 through 41.** The near bank area within 25 feet of water's edge remained similar in character from 1977 through 1980. This left side channel is split again by small sandbars and shoals. Even though the channel is split along this area, velocities are 3 feet/sec at a distance 25 feet from the bankline which equals usual conditions along most structures where channel flows are not divided.

(7) **Range 42 through 47.** In 1977 the flow was strong against the bankline, then shifted away in 1978 when structures were constructed and returned to heavy flow along the bank and the structures in 1980. Conditions of flow velocity and bed scour along this bankline segment should provide a good structure stability test.

b. Significant Observations. All structures constructed at this project area have functioned exceptionally well. Some anticipated minor erosion has occurred in the unprotected bankline areas between structures, but it is all within acceptable limits. This area should be monitored closely in future years because of the larger than normal unprotected gaps between structures along some residentially developed areas. The reduced depths between ranges 5 and 13 can partially be credited to the hardpoints but the major influence was most likely the significant changes in discharge and maybe a change in the percent of flow distribution between the split channel flows on each side of Goat Island.

c. Recommendations. The three methods of erosion protection used at the Vermillion Boat Club Area are very similar to structures at other areas which have been highly successful as they are here. It is recommended that the unprotected bankline areas between structure segments not normally exceed 300 to 400 feet. This is much less than they are actually constructed as an increase in the flow down this side of the split channel could result in increased erosion in the gaps which could affect the entire structure system integrity.

5. BROOKY BOTTOM ROAD PROJECT AREA. This project is located on the right bank and is characterized by a major split flow condition. None of the structures at this project have suffered damage requiring any rehabilitation.

a. Detailed Channel Characteristics. (See Plates 5-1 and 5-2 for Range locations)

(1) Range 0 through 9. This portion of the bankline is composed entirely of intermittently spaced hardpoints. Very little change in the channel depth or velocities in the near bank area (25 feet out from water's edge) has occurred since the predesign hydrographic survey obtained in 1976. The channel bed character has remained irregular and the streamlining of the flow lines adjacent to the bankline which existed before construction has continued through 1980.

The initial structure layout of the hardpoints contained only three hardpoints along this area. Severe erosion conditions in the large gaps indicated that this number was not sufficient and therefore 8 additional hardpoints were constructed. The gaps along this structure system vary from 350 feet to 500 feet and have since functioned very well. Several of the hardpoints were constructed as L-Heads as shown on plate 5-2. This was done because construction of the hardpoint spurs perpendicular to the bankline as normally done would have resulted in significant quantity overruns due to deeper channel conditions encountered during construction.

(2) Range 10 through 15. This convex shaped bankline is composed of two segments of windrow revetment and one segment of composite revetment. The underwater slope along all three segments was relatively flat (1V on 7H) prior to construction. Bed scour quickly steepened the slope to 1V on 3H by September 1978 along the windrow revetment segments. However, as the structure began to function by having the stone material slough in, the underwater slope flattened as anticipated to a much more stable slope of 1V on 6H. The large (800 foot) unprotected area immediately downstream of Composite Revetment 785.5, station 18+00, had a very steep slope in November 1976 of 1V on 2H which has continued through September 1980. The average velocities within 25 feet of water's edge have remained low with very irregular stream lines.

(3) Range 16 through 31. This irregular but relatively straight bankline area is presently composed of 8 intermittently spaced hardpoints and 3 segments of composite revetment. The bed character along this area is fairly uniform with channel depths within 25 feet of water's edge remaining approximately 7 feet to 10 feet since preconstruction conditions in November 1976. Also, the underwater channel bank has remained steep (1V on 2H) from November 1976 to September 1980. The excellent streamlining of channel flows which existed in 1976 and 1977 changed to an irregular flow pattern in 1978 but changed back to its earlier condition in 1979 and 1980.

All hardpoints remain intact and have been in place to sufficiently be tested. The gaps between some of the hardpoints are quite large and could require future rehabilitation to insure project integrity. The composite revetment segments are composed of low grade material which has degraded severely and does not appear to function well when exposed to freeze-thaw and wet-dry conditions.

(4) **Range 32 through 38**. This concave shaped bankline is composed almost exclusively of 8 hardpoints. The only exception is one segment of composite revetment. The upstream half of the area which is not under direct flow attack because of their location at the upstream half of the concave curve have continued to maintain a flat underwater bank slope (1V on 8H) with minimal channel bottom depth changes since structure completion. The downstream half of this area contains very steep underwater bank slopes (1V on 2H) along a constantly changing channel bottom. In addition, the flow lines are very irregular and have not become streamlined at any time since 1976.

(5) **Range 39 through 44**. This most downstream portion of Brooky Bottom Road is composed of four segments of composite revetment which have effectively eliminated the erosion along this area. This irregular channel bed area has an underwater bank slope which has gradually changed from very steep in November 1976 (1V on 2H) to a much more stable slope (1V on 6H) in September 1980. Also, the flow lines along this area have changed and become much more streamlined in this area.

b. **Significant Observations**. The initial Brooky Bottom Road Area design was not adequate because of the large unprotected areas. Therefore, several additional hardpoints were required to provide adequate protection. Because of the large vegetated bar along the entire project area, major split channel flows exist which almost precludes the possibility of the entire area being tested by excessively high flow attacks. Therefore, the hardpoints have a better possibility of success in this area than in another area.

c. **Recommendations.** The use of hardpoints is a viable solution along areas that will probably not be exposed to direct flow attack and where erosion rates are lower. It is difficult to determine an optimum hardpoint spacing interval because several factors influence the effectiveness of a particular spacing including flow direction, soil types, angle of hardpoint construction, length of hardpoint, and channel depths. The L-Heads do not appear to redirect the flows away from the bank to effectively protect the downstream gaps; however, they have functioned adequately. The use of white chalk rock as a substitute for stone is not recommended if placed in the splash zone where it is susceptible to freeze-thaw and wet-dry conditions which breaks down the material and reduces the life of the structure. The use of low grade material may still be acceptable in the lower toe zones below water surface.

6. **MULBERRY BEND.**

a. **Detailed Channel Characteristics.** (See Plate 7-1 for Range locations)

(1) **Range 17 through 30.** From September 1977 to September 1980, hydrographic data indicates that the channel conditions along this portion of the project remained fairly constant. Maximum channel depths within 25 feet of water's edge averaged about 11 feet in 1977 and 12 feet in 1980. The average velocities within 25 feet of the bank have decreased since initial structure completion. Velocities of up to 5.5 feet per second were common along the water's edge in September 1977 but have decreased to a maximum encountered in September 1980 of 4 feet per second.

(2) **Range 31 through 34.** Channel conditions along this portion of the Mulberry Bend Area have significantly changed since initial structure completion in June 1978. Pre-condition conditions in September 1977 showed very deep conditions adjacent to water's edge averaging about 13 feet. Hydrographic data obtained in September 1978 and

September 1980 showed average depths of about 9 feet. Since initial construction was completed the maximum velocities within 25 feet of water's edge have decreased from 5.4 feet per second in September 1977 to about 4 feet per second in September 1980.

b. Significant Observations.

(1) The stone fill revetment segment and composite revetment segment constructed along the upstream half of the project have been very effective in saving the county road which was in imminent danger of being lost to erosion in 1978.

(2) The low grade materials placed in Vane Dike 775.4 and Revetment 775.9 was completed in July 1978. The material is a black or dark gray shale from the Schram Quarry of Fort Calhoun Stone Company out of Ponca, Nebraska.

(3) The low grade rock material on the riverward 15 to 20 feet of Vane Dike 775.4, which is normally under water during the navigation season, has approximately 75 to 85% of the exposed rock degraded into smaller sizes. Only a few rocks larger than 12 inches are present, although project specifications require from 35% to 65% to be larger than 12 inches in size.

c. Recommendations.

(1) Low grade material should not be placed in the portions of the structure exposed to wet/dry cycles or ice. This results in excessive breakdown of the material to an unstable size. The use of low grade material has been proven as less expensive method than all stone of protecting the underwater toe zones only.

(2) The composite revetment constructed has functioned as designed and proven to be a very effective method of streambank erosion protection.

(3) The gravel cover on the structures does not provide any structural benefits and should only be utilized where aesthetics are of concern. The gravel does, however, fill voids in the stone and improve river access by wildlife. The gravel also enhances natural vegetation growth.

(4) A windrow refusal (50 to 75 feet) should be constructed landward into the bank at the upstream end of each revetment segment to eliminate the possibility of erosion flanking the revetment segment resulting in complete structure failure.

7. **VERMILLION RIVER CHUTE**.

a. **Detailed Channel Characteristics**. (See Plate 8-1 for Range locations)

(1) **Range 0 through 8**. This portion of the project is characterized by overbanks in excess of 20 feet above normal water surface. The channel depths have remained uniform since pre-construction hydrographs were obtained in November 1976. Between Ranges 0 and 4 channel depths within 50 feet of water's edge have continued to average approximately 8 feet with channel depths along the toe of the windrow revetment segment located between Ranges 5 and 8 of approximately 20 feet.

(2) **Range 9 through 20**. This portion of the project area is characterized by bank heights ranging from 8 to 20 feet above the water surface. As shown on Plate 8-12, this portion of the project has shallow depths which have not changed much during 1976 through 1980 within 75 feet of the left bank. Associated with the shallow depths are very low average velocities within 50 feet of the water's edge.

(3) **Range 21 through 30**. The portion of the Vermillion River Chute Area has been under attack by the main flows of the Missouri River since initial construction completion in 1976. Velocities in this area range from 1.4 to 5.5 feet per second. As is shown on Plate 8-13, most of this area has had a scour trend rather than any trend for

bar buildup. As shown on Plate 8-13, the rear bank water depths have maintained very deep conditions, with average near bank channel depths of 10 to 15 feet, with maximum depths of 25-30 frequently encountered.

b. **Significant Observations**.

(1) **Range 0 through 8**. In this portion of the project there are two segments of composite revetment and two segments of windrow revetment. The windrow revetment segment constructed between approximate Ranges 5 and 8, has caused the bankline to become more uniform. This has resulted in a reduced roughness coefficient which combined with the fact that the majority of the flow is concentrated along this left bank area has resulted in increased velocities adjacent to the bank The increased scour along the toe of Windrow Revetment 771.9 is directly related to the increased velocity.

The objective of using constructed Windrow Revetment 771.9, from station 25+00 to 39+00, was to test the performance of this method of bank protection under extreme conditions and to prove that it is an effective environmentally acceptable erosion control technique. Any other technique would be very difficult to construct since implementation of the windrow method allows work on the upper bank rather than along the toe of this very high bank area.

During the summer of 1979, the area along the most upstream portion of the project near the Vermillion River suffered approximately 60 feet of lateral erosion. Therefore, in the Fall of 1979, Revetment 772.0 and Windrow Refusal 772.01 were constructed. Without this additional protection, Revetment 771.9, station 0+00, and Windrow Refusal 771.91 would undoubtedly become flanked resulting in severe erosion losses and damage to several homes located in this area. Presently, an area of the windrow revetment approximately 150 to 200 feet downstream from the Vermillion River confluence is "active" and excessive erosion is no longer a threat.

(2) <u>Range 9 through 20</u>. This portion of the project is composed of four segments of reinforced revetment, four hardpoints, and one segment of composite revetment. Due to the low average velocities and shallow channel depths along this portion of the project area, all of the structures between ranges 9 and 20 have not been tested to date. This area may, however, become active with any future shifts in the main channel of the Missouri River.

(3) <u>Range 21 through 30</u>. This downstream portion of the project, along the Ponderosa development, is protected by one segment of windrow revetment, three hardpoints, and four segments of composite revetment. The unprotected bankline areas between the composite revetment have been protected by additional composite revetment since construction of the original segments due to excessive erosion in this gap. The change in the right bank slope has resulted in a forcing of flows toward the left bank. As the right bank has changed continued erosion, the angle at which water has been forced toward the left bank has changed accordingly.

(4) <u>Recommendations</u>.

(1) Windrow revetment is a very effective method of erosion protection along actively eroding banklines characterized by very high steep banks with deep near bank channel conditions. Initial stone material application rates of 4.5 tons per linear feet is usually adequate for high bank areas to reach a stable condition.

(2) Windrow revetment should only be constructed along already cleared upper bank areas because construction in timbered areas would require considerable clearing.

(3) The reinforced revetment structures located near the center of the project have not been adequately tested, due to minor flows along this area, to reach any recommendations at this time. However, changes

in channel conditions could occur and therefore continued monitoring in this location should continue in order to evaluate their effectivness. The principles for locating and spacing reinforced revetment segments along the bank are virtually identical to composite revetment.

(4) Composite revetment is generally used where river depths adjacent to the bank are substantial, thus eliminating the requirement for significant to excavation. Also, composite revetment is applicable along heavily timbered banks because only minimal clearing is necessary.

(5) Little variation occurred between the various upper bank treatments utilized on the composite revetment segments. All materials (stone, gravel, clay, filter cloth and installed vegetation) all performed equally but are unneeded. Experience obtained at other demonstration sites indicates that a composite revetment stone toe with a gravel cover constructed entirely riverward of the high bank with no upper bank grading is structurally as effective, with less environmental disturbance.

(6) The use of low grade material in windrow revetment is not recommended due to extreme conditions breaking down the material. Low grade material should only be utilized in the lower toe zones of composite revetment.

(7) The unprotected bankline areas between the 3 hardpoints located in the Ponderosa development at the lower end of the project are too large (350 feet). Hardpoint spacing is dependent on specific site conditions. The average hardpoint system should have spacings not exceeding 250 feet.

(8) The unprotected bankline areas between revetment segments range between 300 and 1,300 feet. Under normal conditions, the unprotected areas should not exceed 250 feet to provide optimum

protection; however, the exact spacing is dependent on specific site conditions.

(9) The minimum revetment segment length should be 400 feet.

(10) Each revetment segment should contain a 50- to 75-foot windrow refusal composed of stone extending landward into the bank at the upstream end of the segment to eliminate the possibility of erosion flanking the revetment segment resulting in complete structure failure.

8. RYAN BEND PROJECT AREA.

a. Detailed Channel Characteristics. (See Plate 9-1 for Range locations)

(1) **Range 18 through Range 1.** This portion of the project has developed a shoal (between 1977 and 1978) ranging from 1.5 to 3 feet in height. Revetment structures were constructed in 1979 and range data taken in 1980 reflects the shoal has scoured away and water depth increased to levels of 5 to 9 feet below the 1977 bed levels. Some of these changes can be attributed to adjustments in flow between the right and left channels as this is a split channel location. A portion of the bed lowering (1978-1980) resulted from flow streamlining along the revetment segments.

(2) **Range 1 through Range 5.** In the next bankline segment downstream the bed scoured down about 4 feet (1977-1978) and then aggraded between 1978-1980 by an average of 7 feet above the 1977 levels. This shoal buildup resulted from the bankline alignment that developed a deeper concave shape in the upstream erosion area which directed the flow toward the downstream bank area of the right bank near Range 5.

(3) **Range 5 through Range 12.** This portion of the right bankline has flows which have remained concentrated since 1977 and has deepened

a d consolidated during the 1978-1980 period. Erosion pressure by the flow in unprotected areas will be strong and refusals may approach failure conditions by 1982. Heavy bed scour along revetment toe areas will also test the strength of the revetment designs.

(4) Range 12 through Range 13. This downstream portion of the project shows some bed lowering in the upstream 1/2 area and shoaling in the downstream 1/2 area. General shoaling should develop along the total 1,100 feet unless mid-channel bar formations change to force the flow into this area.

b. Significant Observations. Overall, most of the structures at the Ryan Bend Area project site have functioned very well to resist erosion in a previous severely eroding bankline. An exception is Windrow Revetment 767.5, station 21+00 to 27+00, which is the most downstream segment of revetment in the project area and has experienced considerable damage due to material displacement in the toe needed to stabilize the bank. The unprotected bankline gaps upstream of Windrow Refusals 768.2, 767.85, 767.51, 767.42 and 767.2 have all experienced considerable erosion which could possibly flank the windrow refusals and result in severe unraveling damage to the downstream revetment segments. This erosion, which could eventually effect the functional stability of the entire structure system, is not an indicator of the effectiveness of the reinforced revetment structures. This scalloped erosion damage does indicate that the unprotected areas between structures, which range from 235 feet up to 400 feet, are too large for the present direction of channel flow erosion conditions. This increase in erosion in the unprotected areas can be attributed to flow adjustments between the right and left channels at the split channel location. In addition, a previously existing shoal along the area has been scoured away and water depths throughout the reinforced revetment area, where the erosion has increased, has changed to levels of 5 to 9 feet below the 1977 bed levels.

The low grade material (black shale) utilized in the toe of the reinforced revetment segments at a rate of 3.5 tons per linear foot of bankline has functioned considerably well; however, several areas have suffered minor scallops due to channel degradation, which appears to be becoming more widespread throughout the project area. It is anticipated that the reinforced revetment structures will require some remedial reconstruction in the summer of 1981.

The stone tiebacks constructed for the reinforced revetments range in spacing from 80 feet c-c to 160 feet c-c. All tiebacks appear in excellent condition, however, they have not been tested by sustained high flows.

All three composite revetment and three windrow revetment segments have functioned very well and have received no damage.

c. **Recommendations**. The reinforced revetment toe crown elevation should be lowered approximately 2 feet to allow flows to overtop the toe material and utilize the purpose of the stone tiebacks. The tiebacks have not been tested properly and therefore no tieback spacing can be recommended from this project.

Even though the low grade material (black shale) utilized in the toe of reinforced and composite revetment is not comparable in the quality and lifespan of stone, it is a viable alternative where stone is not readily available.

The unprotected gaps between the structure segments should not normally exceed 300 feet where the flow streamlines are parallel to the bankline. In areas where the bankline is under direct attack or the channel configuration could easily change and create this situation, the unprotected area should be approximately 200 feet.

9. **IONIA BEND PROJECT AREA.**

a. **Detailed Channel Characteristics.** (See Plates 10-1 and 10-2 for Range locations)

(1) **Range 1.0 through 1.2.** Very little change occurred in the near bank area (within 25 feet of water's edge). The average velocity within 25 feet of water's edge ranged from 2 to 3 feet per second between 1978 and 1980. The bed character remained uniform along this area protected by a large segment of composite revetment.

(2) **Range 2.0 through 2.2A.** The channel depths along the near bank became considerably deeper after construction of the series of 6 hardpoints. In 1978, channel depths averaged approximately 9 feet but by 1980, average depths exceeded 12 feet. Prior to construction higher velocities were concentrated along this area, as shown on Plate 9-12, however, after the hardpoints were constructed the flows were redirected away from the bank as anticipated.

(3) **Range 2.3 through 3.2A.** The portion of the project experienced severe erosion prior to construction. The bankline configuration has caused direct flow attack along this area. Channel depths prior to construction in June 1978 and since completion have been very deep with a very irregular shaped channel bottom.

(4) **Range 3.3 through 4A.** Channel depths within 25 feet of the high bank have significantly decreased since structure completion with the formation of a narrow shoal along the location of the hardpoints. The near bank channel bottom along this area has changed from being very uniform to a very irregular shape.

(5) **Range 4.2 through 6.** This portion of the project area contains cleared upper banks and is exclusively protected by four (4) segments of windrow revetment. Near bank channel conditions have not

changed much since structure completion in September 1978. Some minor erosion is occurring in the unprotected gaps between the segments.

(6) **Range 6.A through 9.1A.** This most downstream portion of the project is protected by two segments of composite revetment along the bankline and a segment of composite revetment along the upstream portion of the vegetated island located near the project bankline. Channel conditions along the toe of Revetment 760.41 station 0+00 to 4+00 has not changed since June 1978 with channel depths remaining very shallow. However, conditions along the other segment of composite constructed on the bankline has and through the chute between the island and the bank has changed significantly from a very deep condition with swift velocities causing severe erosion to a very shallow condition with low velocities.

(7) **Range 9.1A through 12A.** This portion of the project is protected entirely by four segments of reinforced revetment. Channel depths have not changed between June 1978 and 1980 with channel depths remaining approximately 7 to 10 feet and maximum velocities within 25 feet of the bank ranging from 3 to 4 feet per second.

b. **Significant Observations.**

(1) The project has been very effective in eliminating the erosion along a previously severe eroding bankline.

(2) Both hardpoint series are suffering some erosion in the unprotected bankline areas between structures, but have been very effective in reducing the overall erosion losses. Their construction on the downstream side of a convex shaped bank have assisted in the hardpoints maintaining their integrity by not subjecting them to direct attack by the flows.

(3) The stone in the windrow revetments continues to slough along the bank and have not reached a stable condition yet. It appears that the available material in the windrow should be sufficient.

(4) The protection placed on the island has eliminated additional erosion losses to the island.

(5) The four reinforced revetment segments at the lower end of the project have all been effective in eliminating the erosion. However, the erosion in the unprotected areas between segments have suffered extensive erosion and will undoubtedly require rehabilitation by extending the windrow refusals landward shortening the unprotected bankline areas between structures.

c. __Recommendations__.

(1) Hardpoint systems should only be constructed along relatively straight or the downstream half of a convex shaped bank area so as not to be exposed to direct flow attack. In most cases, hardpoints are not as an effective method of erosion control as segmented revetment.

(2) The hardpoint spacing interval of 200 feet is optimum for channel conditions similar to those areas where hardpoints were constructed at the Ionia Bend Area. The maximum spacing between hardpoint structures should not exceed 300 feet.

(3) The riverward toe crown elevation of composite revetment should not exceed the NWS.

(4) Gravel cover over the crown of the composite revetment stone is necessary if aesthetics is of concern. The gravel does not provide any structural improvement, other than providing easier access to the river by wildlife and increasing natural revegetation growth.

10. ELK POINT (PHASE I AND PHASE II) PROJECT AREA.

a. Detailed Channel Characteristics. (See Plates 11-1 and 11-2 for Range locations)

(1) Range 73 through 54. In May 1979, the channel depths 25 feet from water's edge averaged approximately 10 feet along this portion of the project, with maximum near bank velocities of only 1 to 2 feet per second. By September 1980, only a couple months after completion of the construction in this portion of the project, the channel conditions were average channel depths of 7 feet and even lower maximum velocities of 0.5 to 2.0 feet per second. This portion of the project completed under Phase II, was not suffering near the erosion as most other areas along the project site.

(2) Range 53 through 41. Channel depths and velocities along this portion of the project have caused severe erosion losses of prime river bottom land. Hydrographic data obtained in May 1979, four months prior to construction in this area, indicated very deep channels within 50 feet of water's edge averaging 15 feet with maximum velocities 4 to 5 feet per second within 25 feet of water's edge. By September 1980, the average channel depths within 50 feet of water's edge had increased to 17.5 feet and the maximum near bank velocities had increased to 7 feet per second. In May 1978 the underwater bank slopes averaged about 1V on 1.9 H and became steeper in September 1980 when the underwater bank slope averaged 1V on 1.7H.

(3) Range 40 through 17. Hydrographic data indicates that the characteristics along this portion of the project did not change significantly from May 1979 to September 1980. The average depth within 50 feet of water's edge remained at 8.5 feet, the average maximum velocity remained about 4 feet per second and the average underwater bank slope changed only from 1V or 2.9H to 1V on 3.1H.

(4) **Range 16 through 1**. In May 1979, the channel characteristics were fairly uniform over this entire portion of the project. Channel depths within 50 feet of water's edge averaged about 7 feet. The average underwater bank slope was approximately 1V on 3.5H for this entire portion and average maximum velocities ranged between 3 and 4 feet per second. By September 1980, this portion of the project converted to a very irregular shaped bank area. The channel depths averaged about 9 feet within 50 feet of water's edge; however, the range varied from 2 to 17 feet. The average near bank velocities remained about 3 to 4 feet per second. Also, the average underwater bank slope of 1V on 3.8 H was not much of a change from the 1V on 3.6H average in May 1979.

b. **Significant Observations**.

(1) The Phase II structure at the upstream 3,600 of the project area have not been adequately demonstrated because the erosion along this area has not been significant since completion in August 1980.

(2) Windrow Revetment 756.05 station 0+00 to 4+00 and station 7+00 to 12+50 are continuing to slough in as designed and the 4.5 tons of stone per linear foot of bankline should be adequate to reach a stable condition.

(3) The bankline where Revetment 755.7 was to be initially located from the December 1978 bankline survey drastically changed between that time to actual construction in Fall of 1980, as shown on Plate 11-1 . In addition, considerable rehabilitation to Revetment 755.7, station 9+66 to 4+00 was required in Spring of 1980 due to the very severe erosion conditions. The entire concave shaped bank where this large structure is located is now entirely protected and will be carefully monitored for effectiveness.

(4) Several unique variations of composite revetment were demonstrated at this site, as shown on Plates 10-4 and 10-5. All combinations utilizing a stone toe, cellular concrete blocks on the upper bank, erosion control fabric, gravel, and earth fill have functioned equally well. Some of the cellular concrete blocks have been displaced slightly due to high bank runoff, but are still structurally sound.

(5) The hardpoint series located near the center of the project, which contains 6 hardpoints, is functioning very well since completion in February 1980. These structures are in an optimum location for hardpoints, the downstream half of a convex shaped bank area.

(6) All other structures including reinforced revetment structures are functioning as designed and are effectively eliminating the previous severe erosion conditions.

c. **Recommendations**.

(1) Hardpoint systems should be placed along bankline areas where the flows are not directly impingent on the eroding bank. A good example is the downstream half of a convex shaped bank area.

(2) The use of concrete cellular blocks on the upper bank of composite revetment is not recommended because of its high material and construction costs. Also, overbank runoff can cause the blocks to easily displace.

(3) The unprotected bankline areas between structures at areas with similar characteristics to this site should not exceed 200 feet because of the severe erosion rates.

(4) A windrow refusal (50 to 75 feet) should be constructed landward at the upstream end of each revetment segment to eliminate the

possibility of flows flanking the structure and causing complete structure failure.

C. CONCLUSIONS FOR THE ENTIRE REACH FROM GAVINS POINT DAM TO PONCA, NEBRASKA.

1. WINDROW REVETMENT.

a. Small gradation (200-pound top size with D_{50} of 7" to 8") stone is more effective in windrow revetment than large gradation (500-pound top size with D_{50} of 9" to 10") stone because the smaller gradation stone forms of more uniform closely chunked protective layer which is necessary to resist erosion of the underwater bank slope.

b. Windrow revetment is very effective in eliminating erosion along areas where the river flows are unusually deep and swift along the toe of the bankline (i.e. Vermillion River Chute Area, Revetment 771.9).

c. After windrow revetment structures reach a stable equilibrium condition, the bank slope revegetate quickly to a more appealing appearance than the pre-construction cutting bank appearance.

d. The amount of stone required in the windrow to reach a stable condition is entirely dependent on site specific channel characteristics. Under conditions encountered on this reach of the Missouri River, 4.5 tons of stone per linear foot of bankline is adequate.

e. Construction is relatively simple and does not require special equipment or excessive construction time and can easily be constructed by both land plant or floating plant construction.

2. **COMPOSITE REVETMENT.**

a. For this reach of the Missouri River from Gavins Point Dam, the toe of the composite revetment should be composed of approximately 4.5 tons of stone per linear foot of bankline. The required material application rate for each specific site is based on the projected anticipated maximum scour depth.

b. Composite revetment should be utilized along actively eroding banks where immediate preservation of the upper bank area is desired and additional erosion losses are not acceptable.

c. Construction by floating plant is recommended over land plant construction; if channel conditions permit and the additional cost can be accepted, because it reduces the environmental impact on the upper bank during construction by eliminating the need for haul roads and upper bank clearing. However, construction of composite revetment by land plant construction requires the least amount of clearing of all revetment type structures demonstrated in this reach of the Missouri River.

d. The maximum stone toe elevation should be 2 feet above the NWS.

e. The various upper bank treatments including: stone, gravel, clay, installed vegetation, filter fabric and cellular concrete blocks are all very similar in their structural effectiveness. Placement of a thin layer of gravel is the simplest and least expensive and therefore is recommended.

f. Composite revetment structures requiring no upper bank grading are recommended over the types with some grading required because of reduced upper bank disturbance and equivalent structure effectiveness.

g. The use of low grade material in the toe of composite revetment should only be placed in the lower toe zones which are

continually underwater to resist possible breakdown due to wet/dry and freeze/thaw effects.

3. **REINFORCED REVETMENT.**

a. The reinforced revetment segments are effective in eliminating erosion with only minor upper bank disturbance required for placement of stone tiebacks and construction activity along the bankline.

b. The optimum tieback interval is 100 feet, however, this can vary depending upon specific channel characteristics.

c. The maximum toe crown elevation should not be higher than 2 feet above the NWS.

d. Reinforced revetment is effective in both shallow and deep near bank channel conditions. Types II and III are constructed where narrow underwater benches exist adjacent to the high bank.

e. The exposed upper bank stone material should be covered with gravel if aesthetics is of concern. Gravel cover does not provide any structural benefit other than allowing easier access to the river by wildlife and enhancing vegetation growth.

f. The maximum crown elevation of the toe of reinforced revetments should be constructed at an elevation which allows normal flows to overtop the crown. This will result in the optimum use of the intermittent tiebacks.

4. **HARDPOINTS.**

a. Hardpoints should only be utilized along straight or convex shaped banklines where the stream flow lines are parallel to the bankline. Hardpoints constructed where the unprotected bankline areas

are experiencing direct attack have in some cases suffered severe erosion in the unprotected areas requiring additional construction to alleviate the problem.

b. The unprotected areas between individual hardpoints may be varied depending on the length of the structure spur and root, the alignment shape of the bankline, and the severity of the present erosion conditions.

c. The recommended length of each hardpoint is 100 feet (50-foot spur and 50-foot root) with an average unprotected spacing between structures of approximately 250 feet.

d. Hardpoints should only be constructed along bankline areas where channel depths are no greater than 10 feet within 50 feet of water's edge to avoid large stone material quantity requirements.

e. The crown elevation of the hardpoint spur should be at or near the normal water surface at the riverward end and a minimum of 5 feet above normal water surface at the landward location.

f. The entire structure should be angled 10° to 20° in the downstream direction from the normal to the bankline.

g. The lower toe zone below normal water surface of the spur should be constructed using a large gradation of stone or low grade material (500-pound maximum size) and the remaining portions of the hardpoint should be constructed using a medium sized stone gradation (200-pound maximum size).

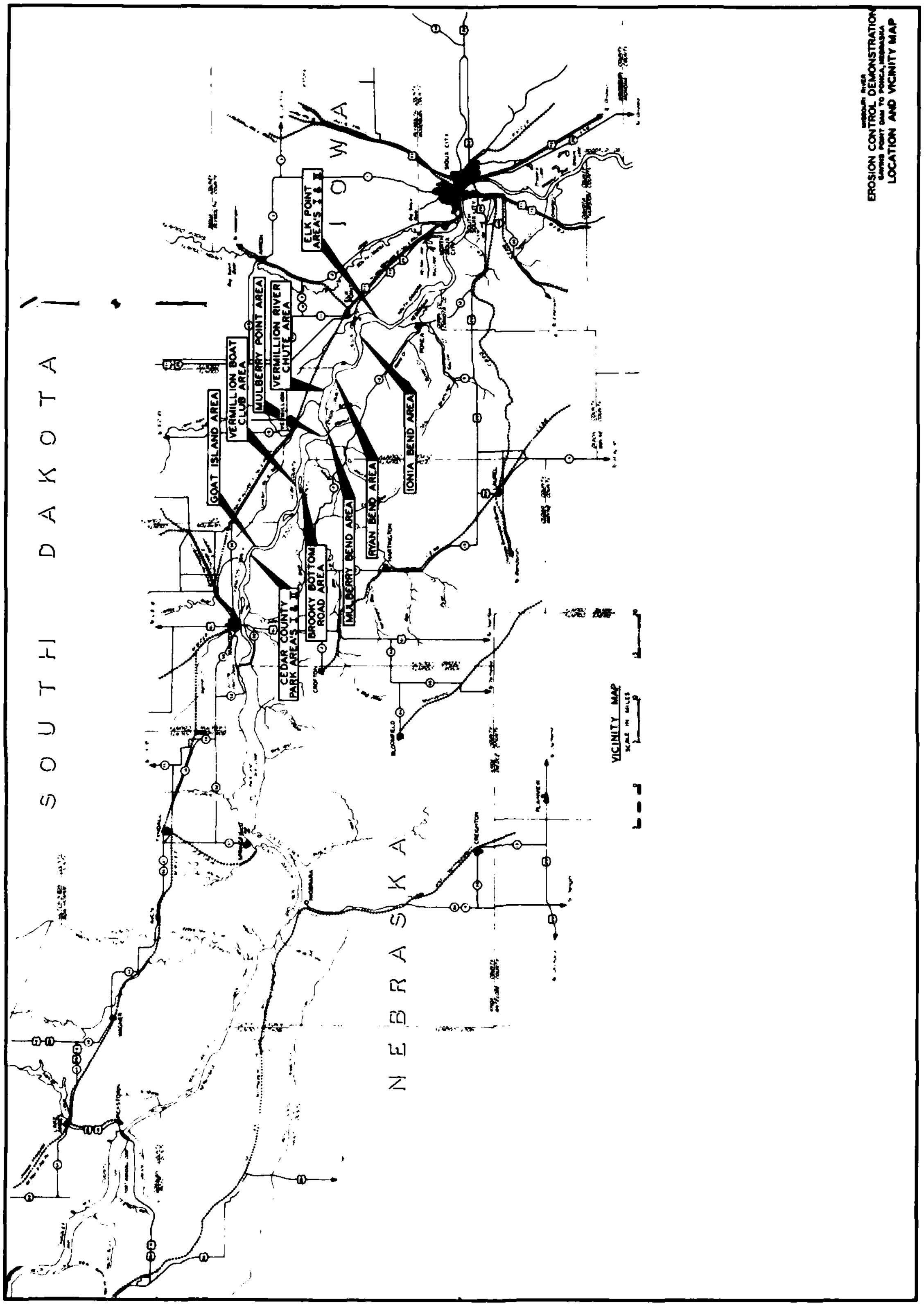

EROSION CONTROL DEMONSTRATION
LOCATION AND VICINITY MAP
SOUTH DAKOTA
IOWA
NEBRASKA
GOAT ISLAND AREA
VERMILLION BOAT CLUB AREA
MULBERRY POINT AREA
VERMILLION RIVER CHUTE AREA
ELK POINT AREA'S I & II
CEDAR COUNTY PARK AREA'S I & II
BROOKY BOTTOM ROAD AREA
MULBERRY BEND AREA
RYAN BEND AREA
IONIA BEND AREA
VICINITY MAP

PLATE 0-1

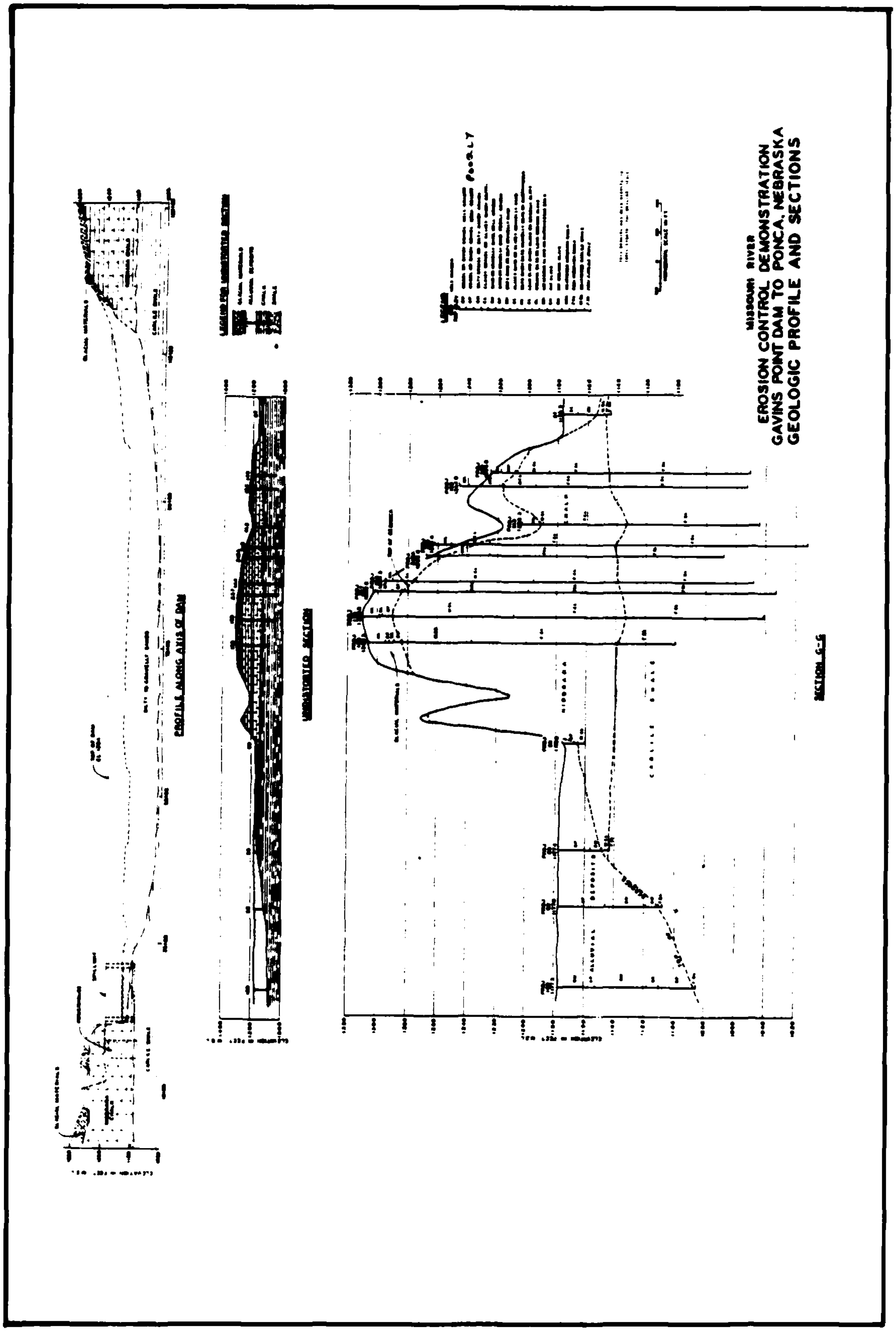

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
GEOLOGIC PROFILE AND SECTIONS
PROFILE ALONG AXIS OF DAM

PLATE 0-2

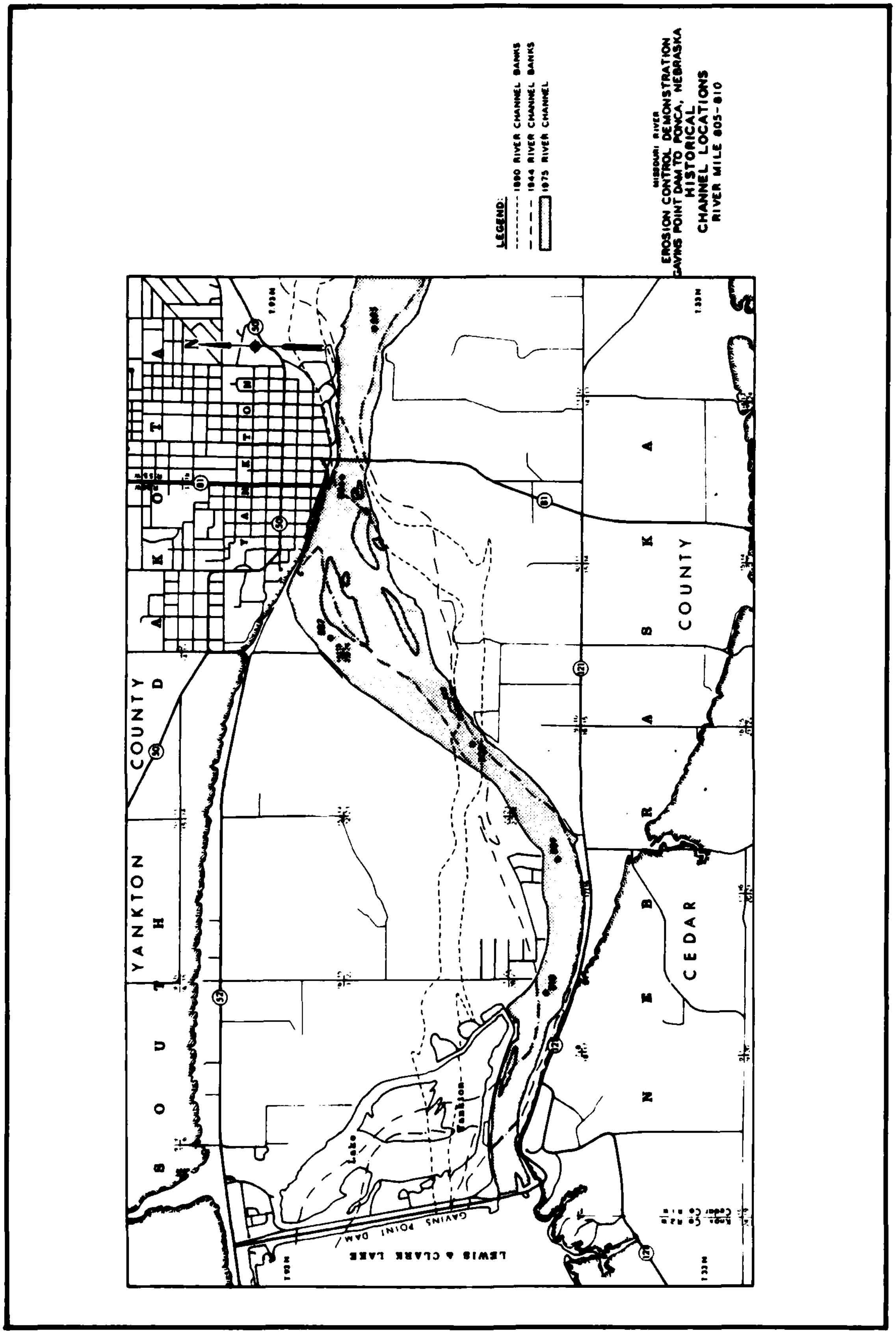
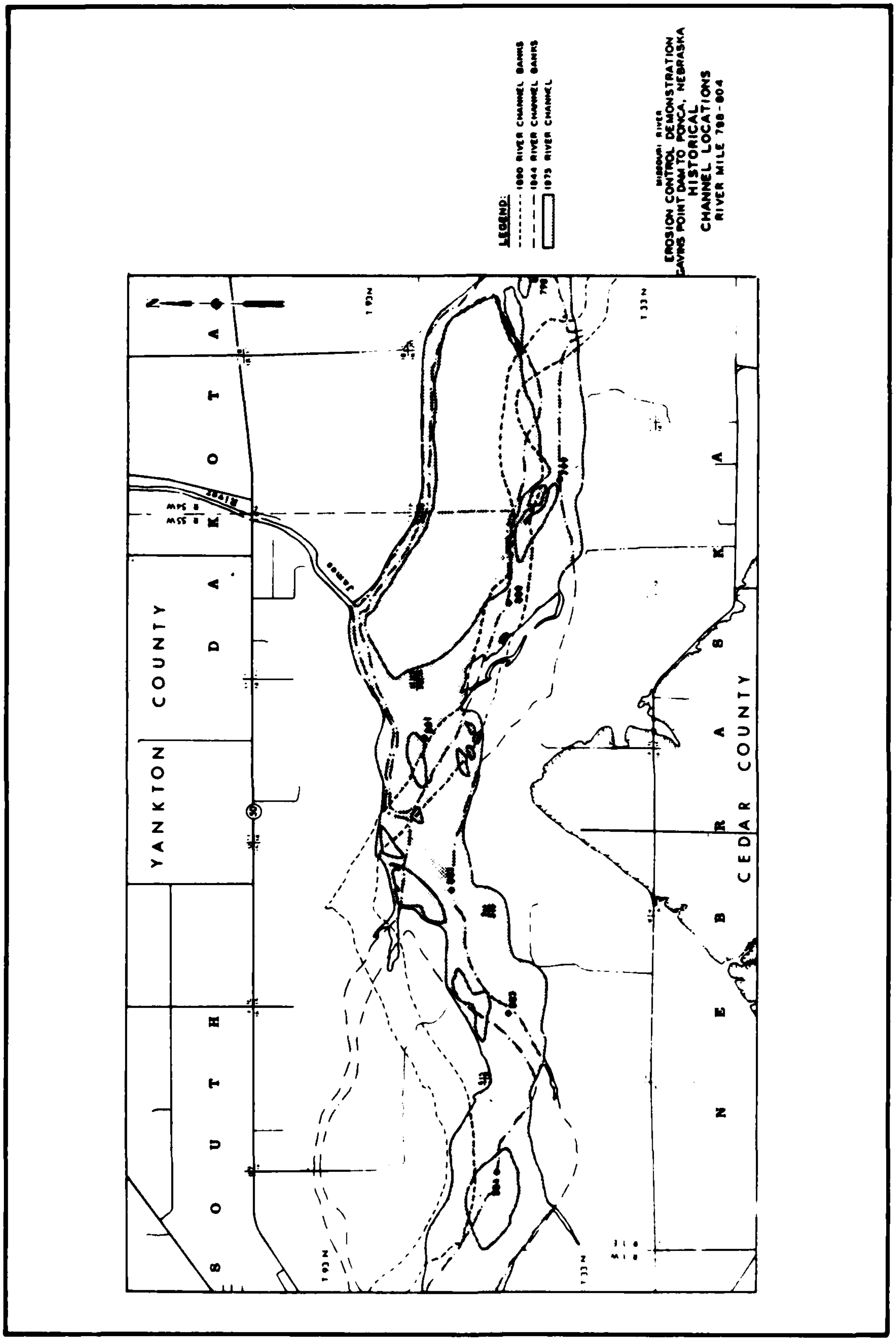

LEGEND:
1890 RIVER CHANNEL BANKS
1944 RIVER CHANNEL BANKS
1975 RIVER CHANNEL
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
HISTORICAL
CHANNEL LOCATIONS
RIVER MILE 805-810
SOUTH DAKOTA
YANKTON COUNTY
YANKTON
NEBRASKA
CEDAR COUNTY
Lake Yankton
GAVINS POINT DAM
LEWIS & CLARK LAKE

PLATE 0-3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1890 RIVER CHANNEL BANKS
1944 RIVER CHANNEL BANKS
1975 RIVER CHANNEL
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
HISTORICAL
CHANNEL LOCATIONS
RIVER MILE 798-804
S O U T H   D A K O T A
YANKTON COUNTY
N E B R A S K A
CEDAR COUNTY

PLATE 0-4

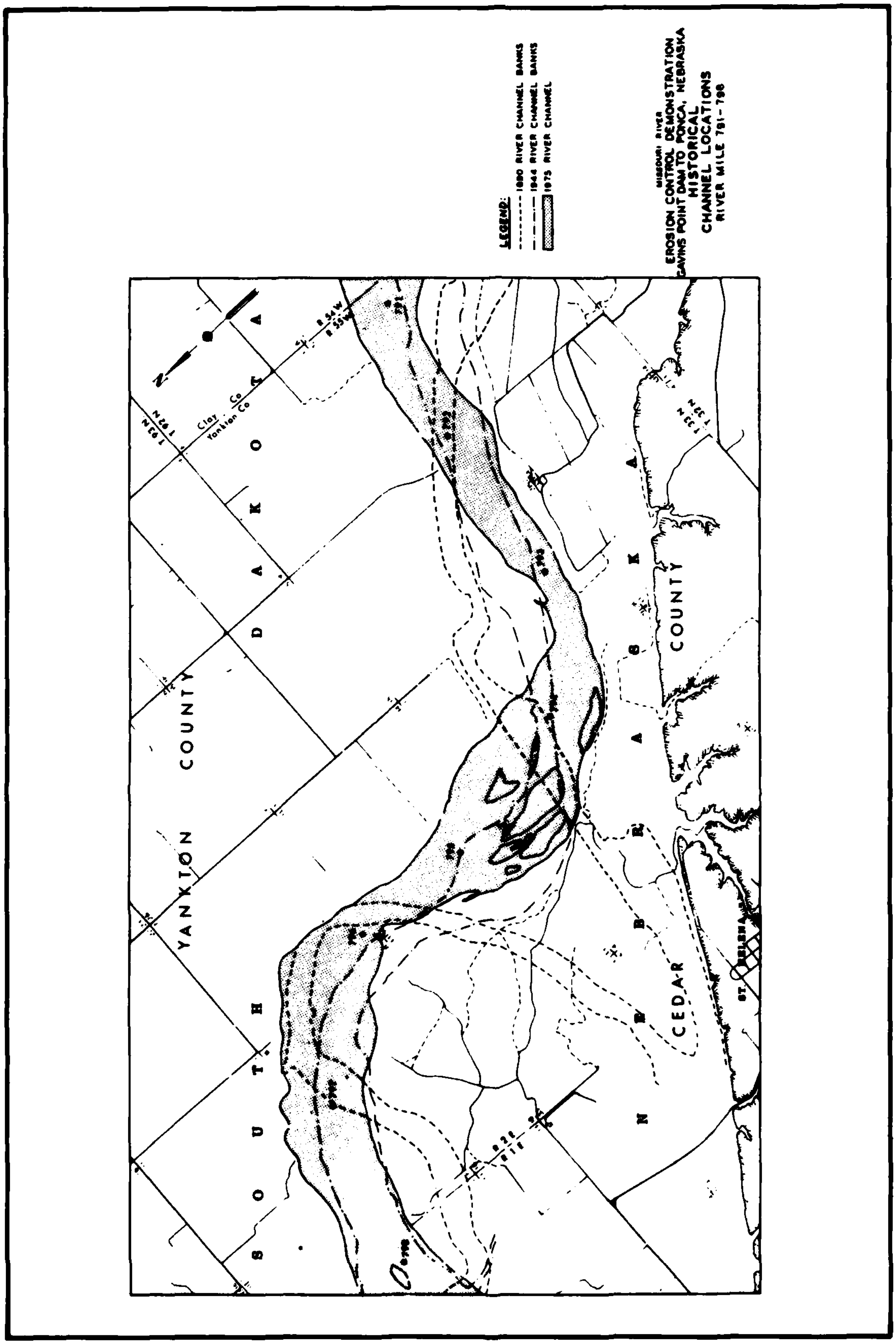

LEGEND:
1890 RIVER CHANNEL BANKS
1944 RIVER CHANNEL BANKS
1975 RIVER CHANNEL
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
HISTORICAL
CHANNEL LOCATIONS
RIVER MILE 791-798
SOUTH DAKOTA
YANKTON COUNTY
Clay Co
Yankton Co
NEBRASKA
CEDAR COUNTY
ST. HELENA

PLATE 0-5

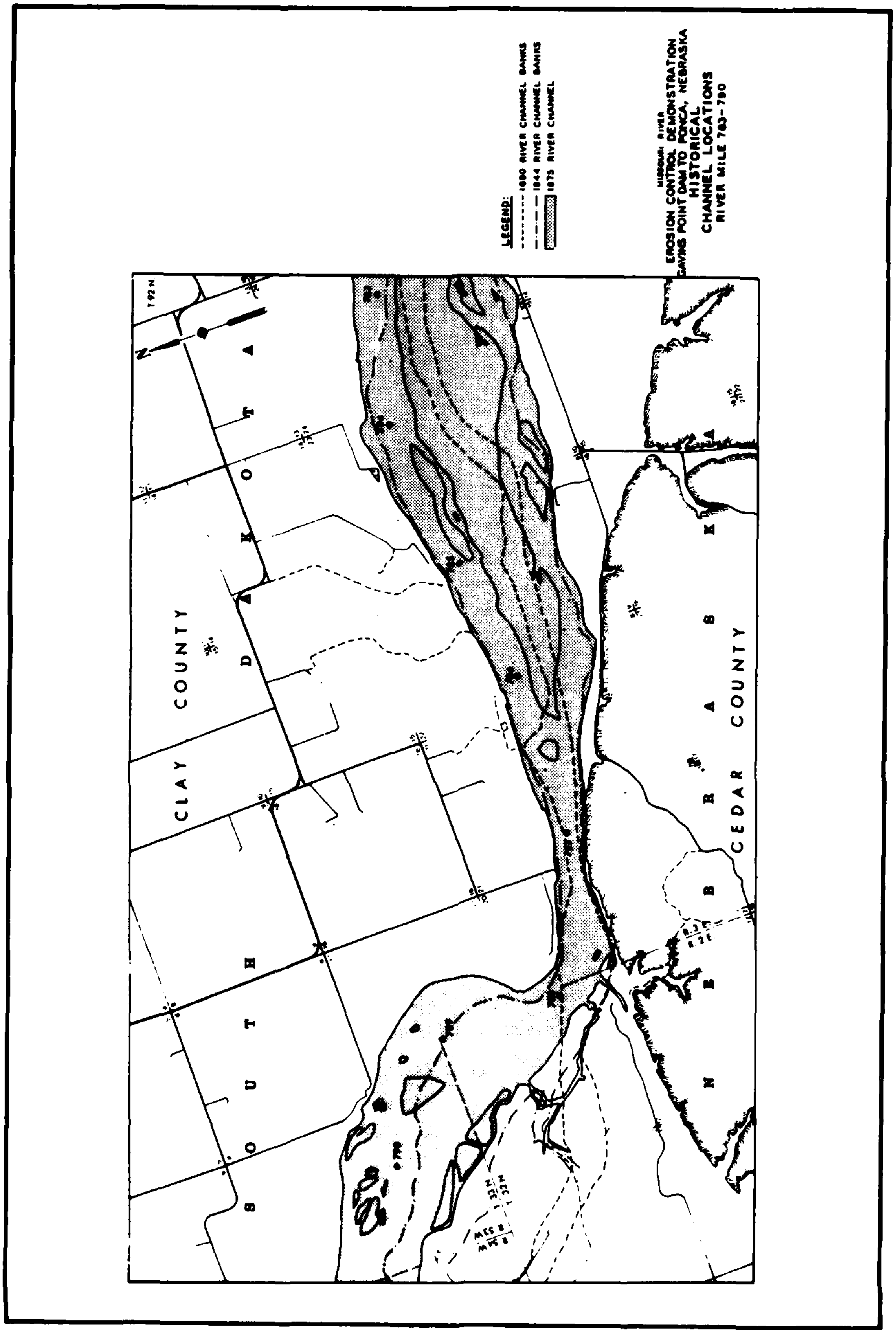

LEGEND:
1890 RIVER CHANNEL BANKS
1944 RIVER CHANNEL BANKS
1975 RIVER CHANNEL
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
HISTORICAL
CHANNEL LOCATIONS
RIVER MILE 783-790
SOUTH DAKOTA
CLAY COUNTY
NEBRASKA
CEDAR COUNTY

PLATE 0-6

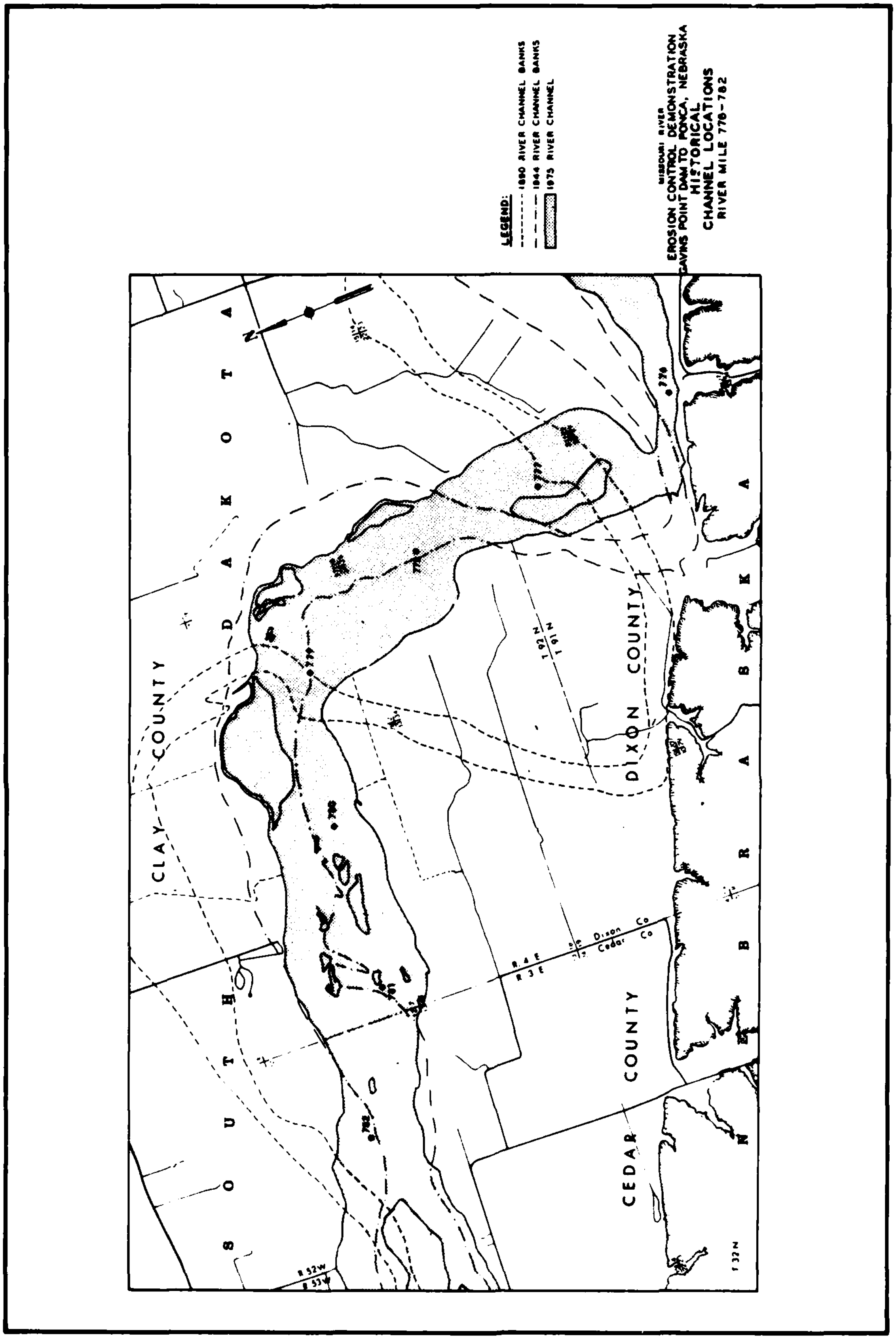

LEGEND:
1890 RIVER CHANNEL BANKS
1944 RIVER CHANNEL BANKS
1975 RIVER CHANNEL
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
HISTORICAL
CHANNEL LOCATIONS
RIVER MILE 776-782
SOUTH DAKOTA
CLAY COUNTY
DIXON COUNTY
CEDAR COUNTY
NEBRASKA
Dixon Co
Cedar Co
R 4 E
R 3 E
T 92 N
T 91 N
T 32 N
R 52 W
R 53 W
776
777
778
779
780
781
782

PLATE 0-7

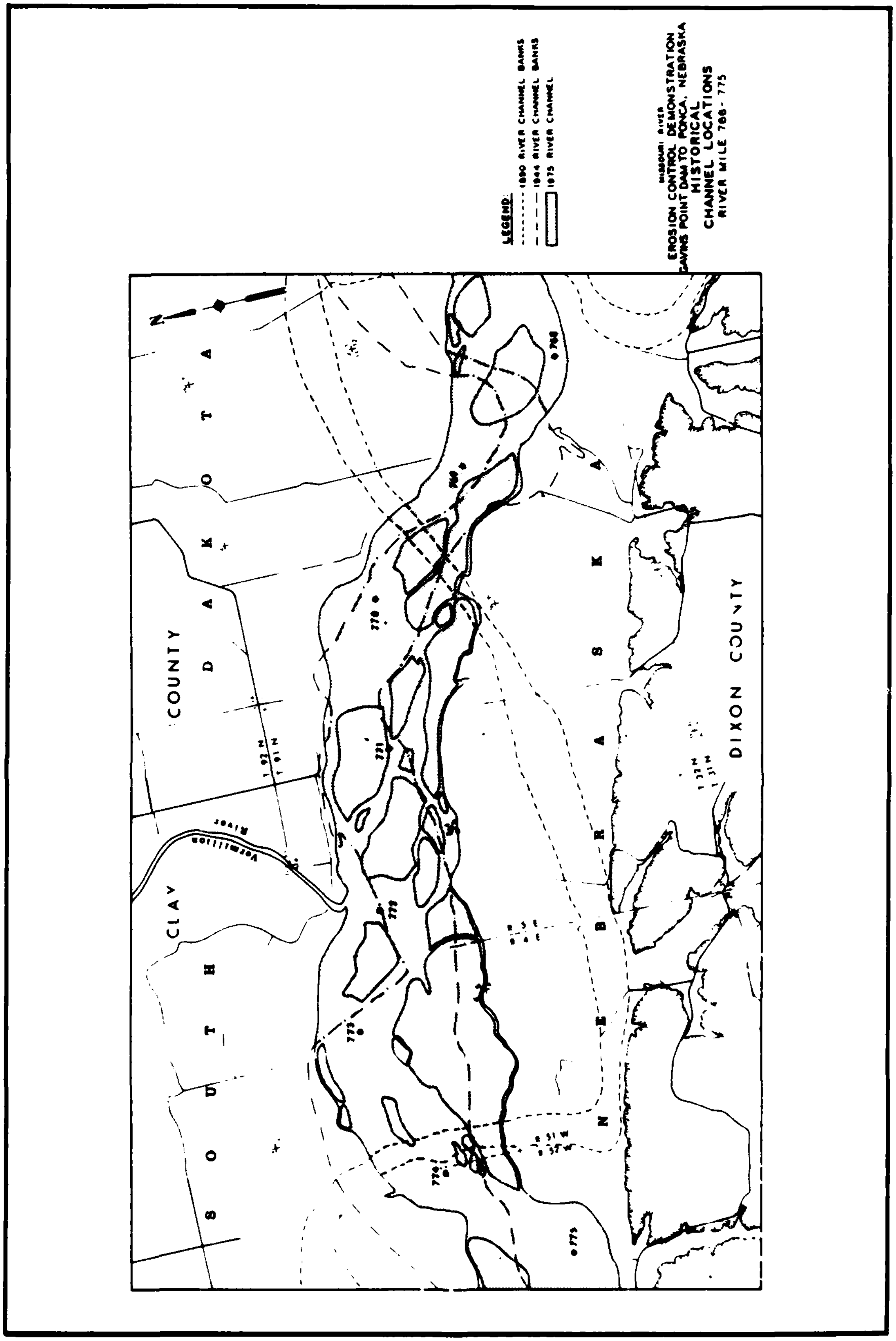

LEGEND:
1890 RIVER CHANNEL BANKS
1944 RIVER CHANNEL BANKS
1975 RIVER CHANNEL
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
HISTORICAL
CHANNEL LOCATIONS
RIVER MILE 788 - 775
SOUTH DAKOTA
CLAY COUNTY
Vermillion River
NEBRASKA
DIXON COUNTY

PLATE 0-8

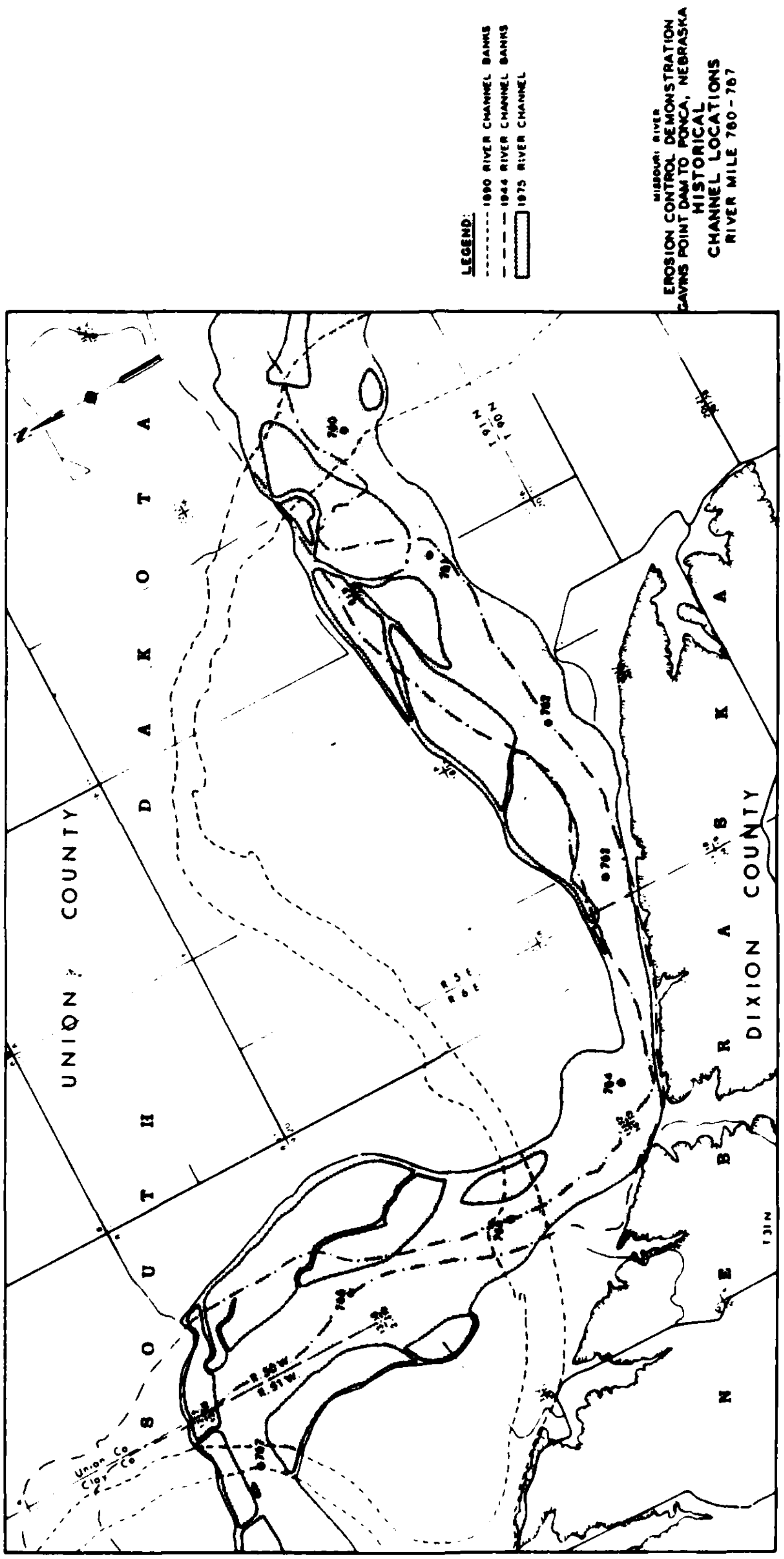

UNION COUNTY
SOUTH DAKOTA
NEBRASKA
DIXION COUNTY
Union Co
Clay Co
T 91 N
T 90 N
T 31 N
780
781
782
783
784
785
787
LEGEND:
1890 RIVER CHANNEL BANKS
1944 RIVER CHANNEL BANKS
1975 RIVER CHANNEL
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
HISTORICAL
CHANNEL LOCATIONS
RIVER MILE 780 - 787

PLATE 0-9

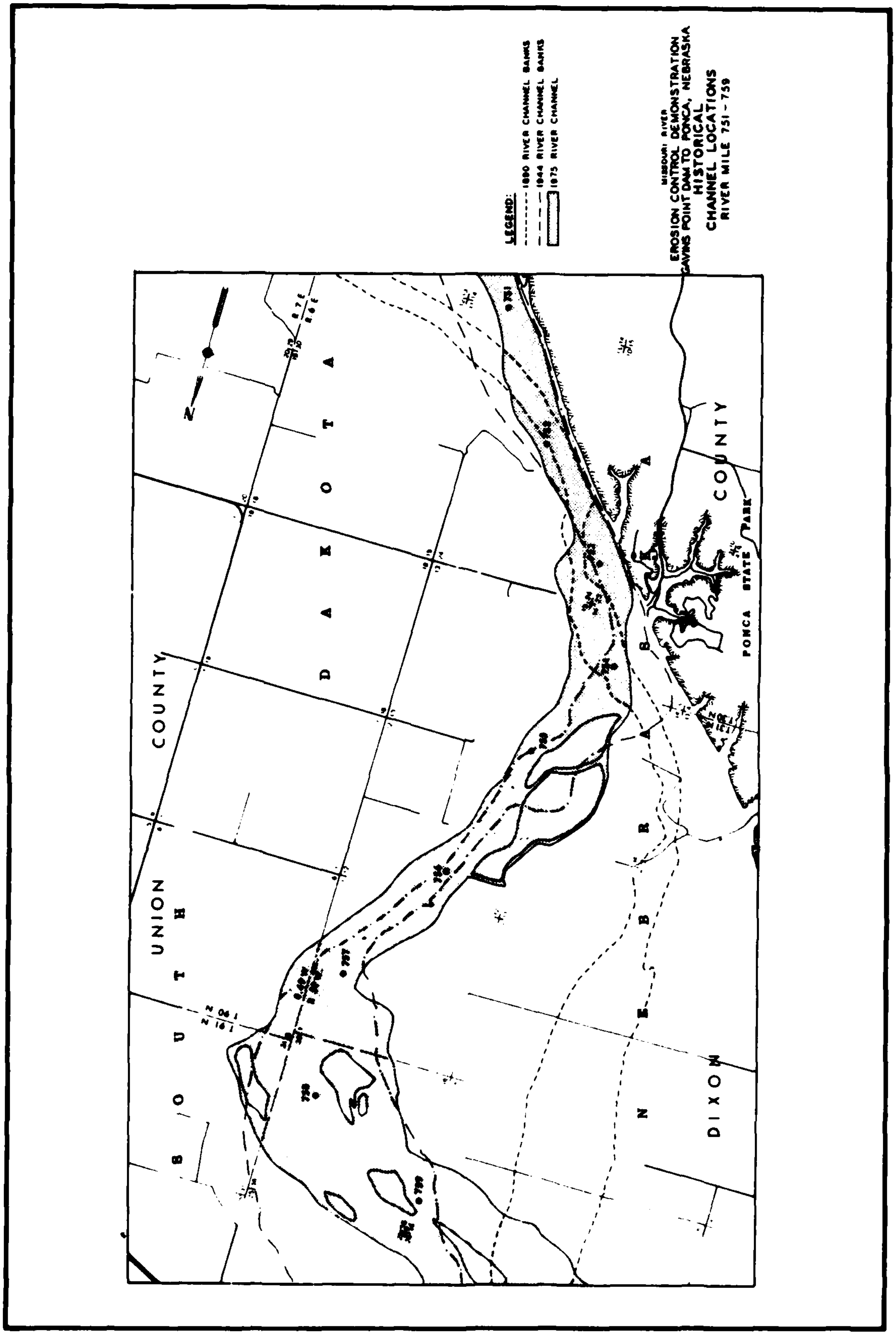

LEGEND:
1890 RIVER CHANNEL BANKS
1944 RIVER CHANNEL BANKS
1975 RIVER CHANNEL
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
HISTORICAL
CHANNEL LOCATIONS
RIVER MILE 751-759
UNION COUNTY
SOUTH DAKOTA
NEBRASKA
DIXON COUNTY
PONCA STATE PARK

PLATE 0-10

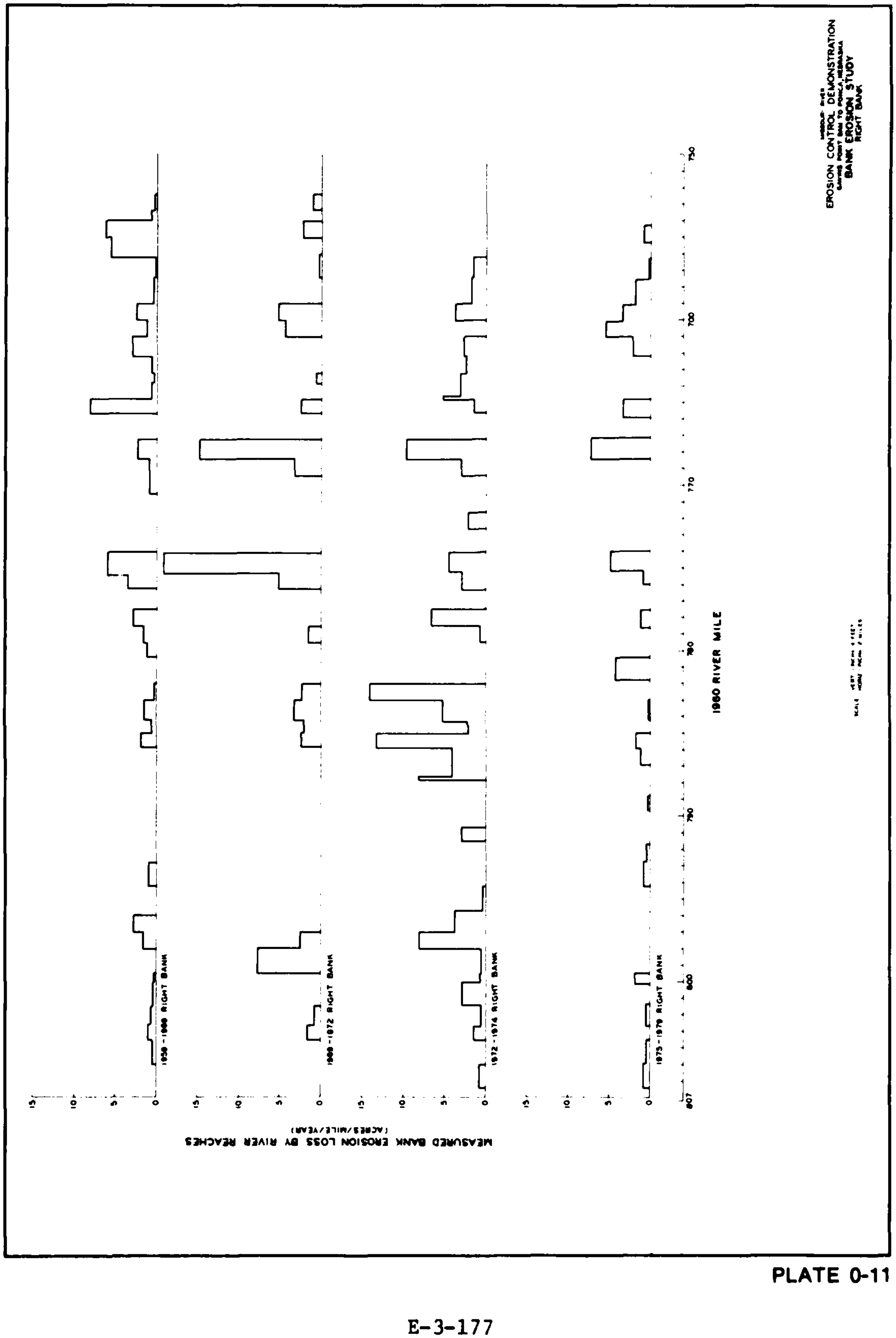

EROSION CONTROL DEMONSTRATION
BANK EROSION STUDY
RIGHT BANK
MEASURED BANK EROSION LOSS BY RIVER REACHES
(ACRES/MILE/YEAR)
1956 - 1966 RIGHT BANK
1966 - 1972 RIGHT BANK
1972 - 1974 RIGHT BANK
1975 - 1979 RIGHT BANK
1980 RIVER MILE
807
800
790
780
770
760
750
15
10
5
0

PLATE 0-11

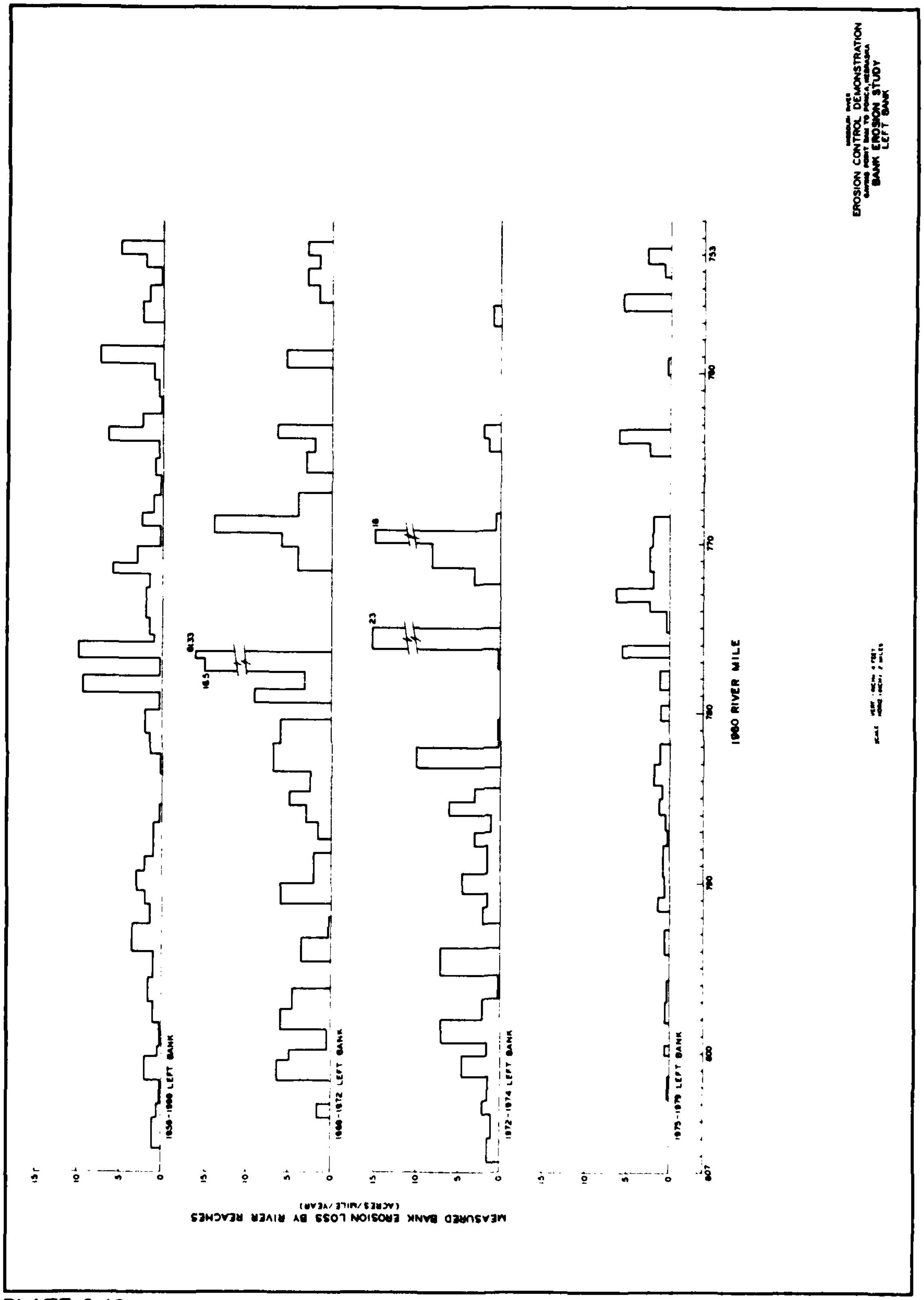

EROSION CONTROL DEMONSTRATION
BANK EROSION STUDY
LEFT BANK
MEASURED BANK EROSION LOSS BY RIVER REACHES
(ACRES/MILE/YEAR)
1960 RIVER MILE

PLATE 0-12

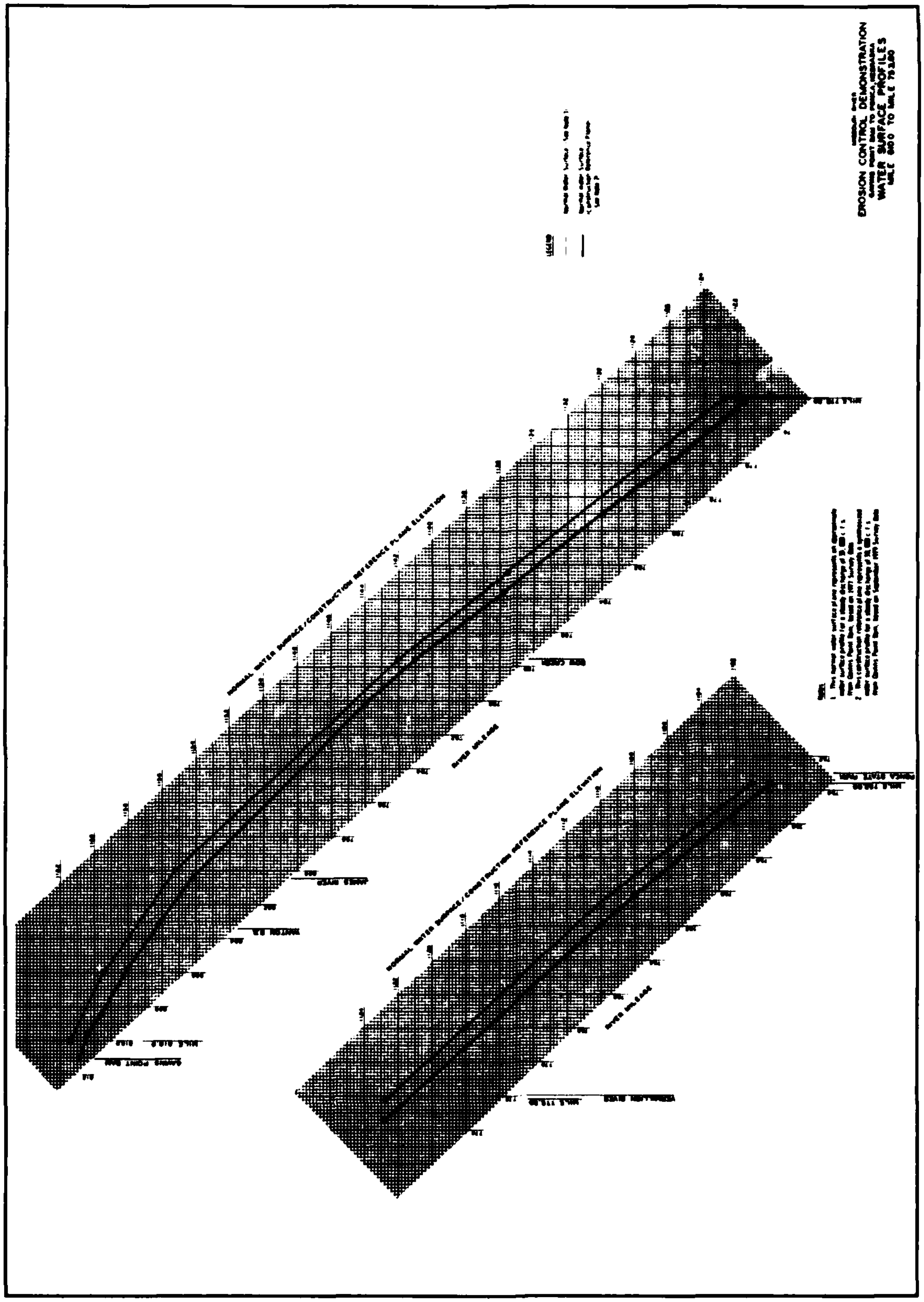
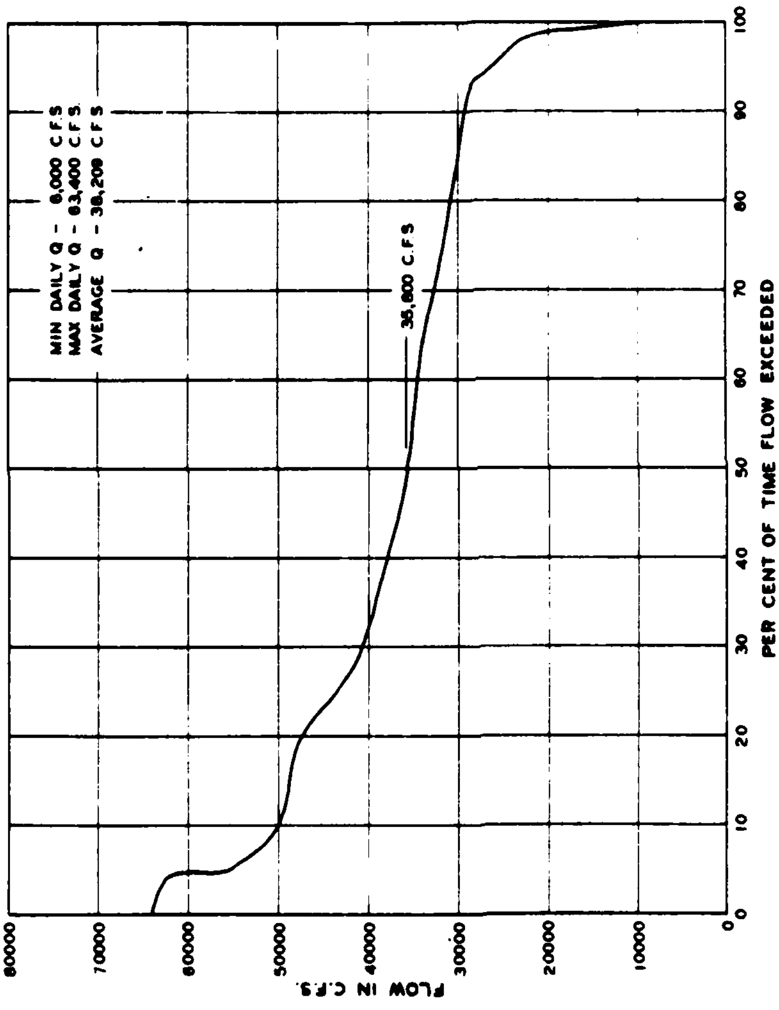


PLATE 0-13

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
FLOW DURATION CURVE



NOTE:
PERIOD APR 01 THRU OCT 31, YEARS 1967 THRU OCT 1976

PLATE 0-14

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA

AVERAGE DAILY GAVINS POINT DAM RELEASE

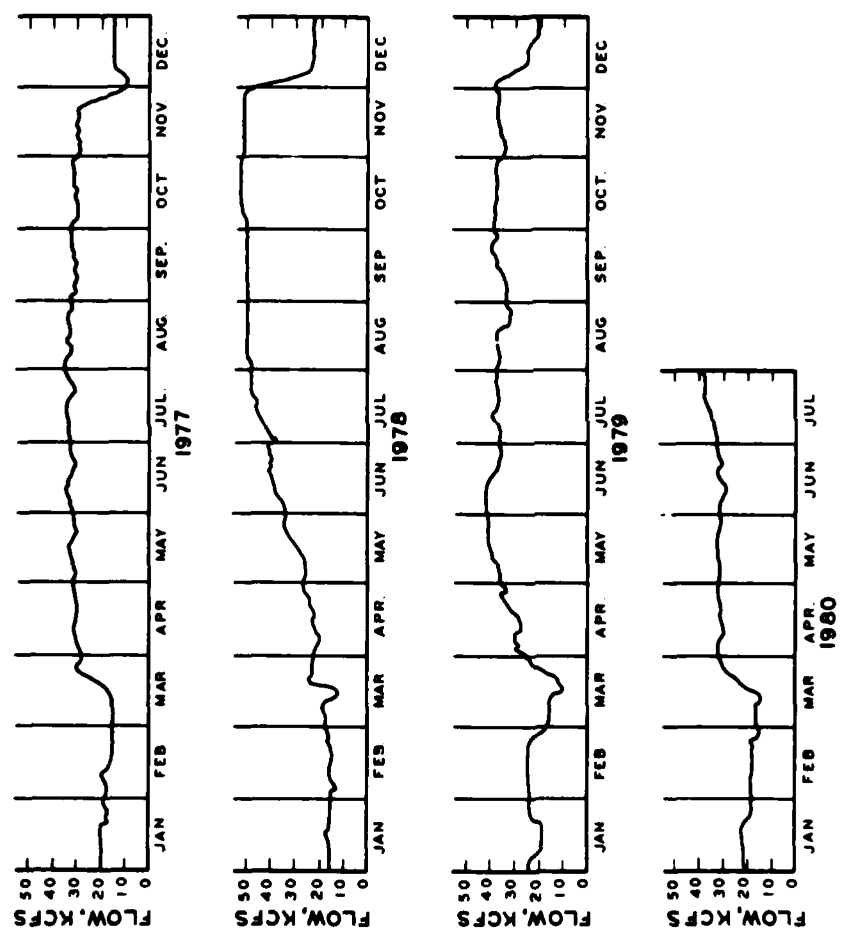
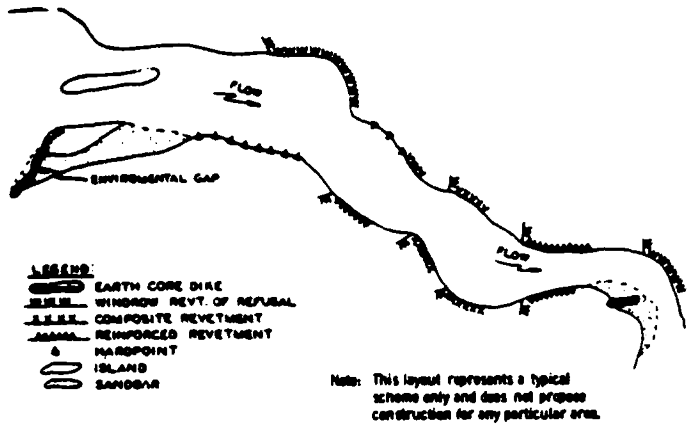
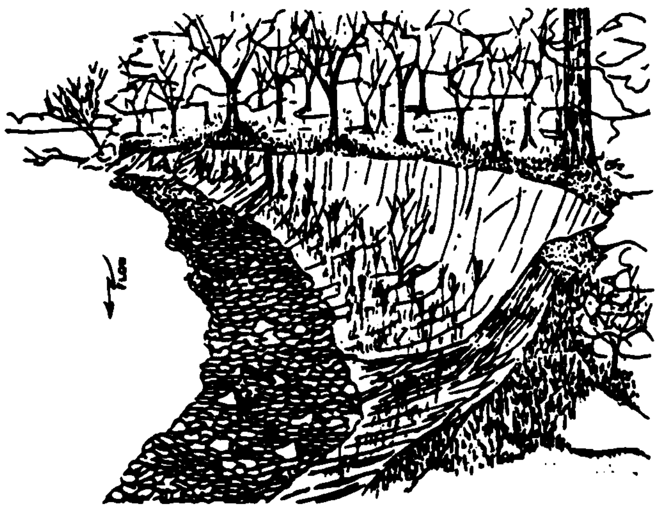


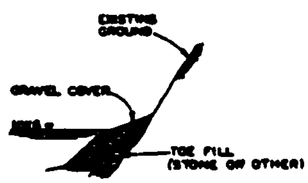
PLATE 0-15



TYPICAL BANK PROTECTION SCHEMES
FOR EROSION CONTROL



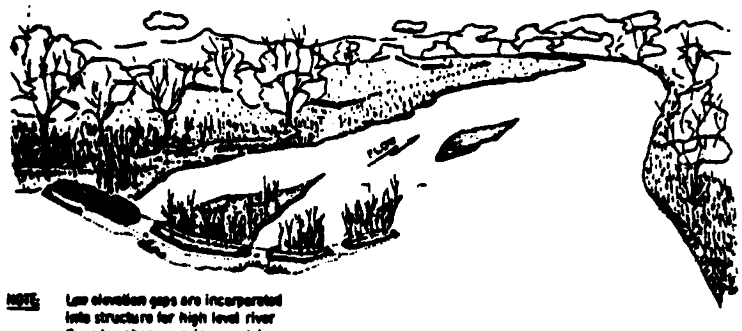
COMPOSITE REVETMENT



TYPICAL SECTION

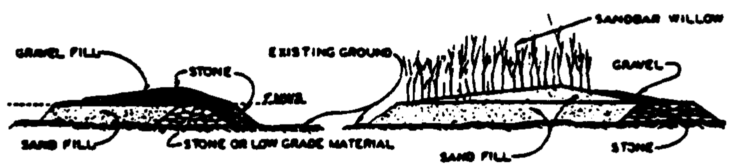
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
TYPICAL BANK PROTECTION SCHEMES

PLATE C 16

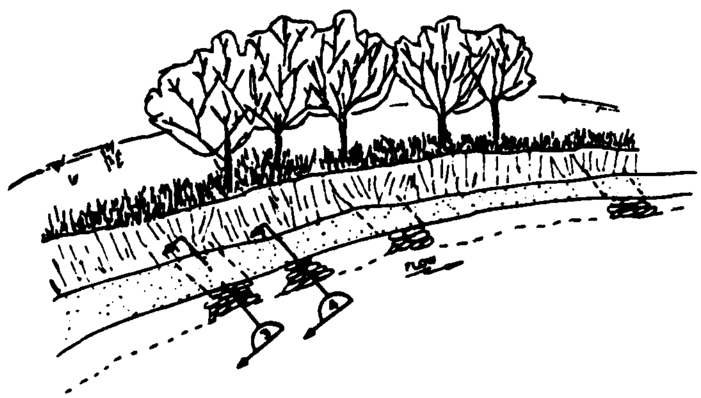


NOTE: Low elevation gaps are incorporated into structure for high level river flows to enhance environmental area downstream.

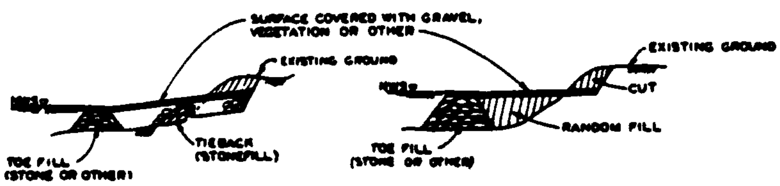
EARTH CORE DIKE



TYPICAL SECTIONS



REINFORCED REVETMENT



SECTION 3 SECTION 4

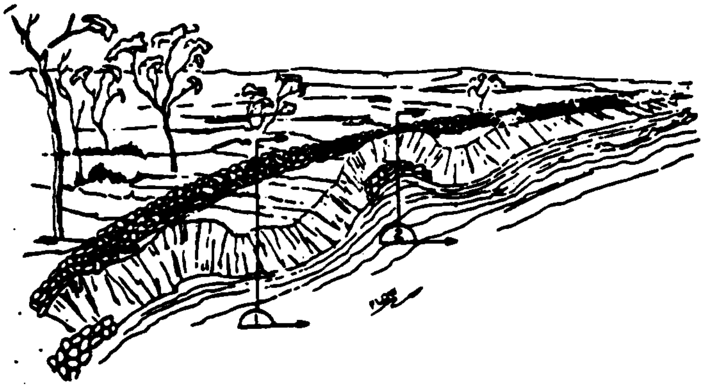
MISSOURI RIVER

EROSION CONTROL DEMONSTRATION

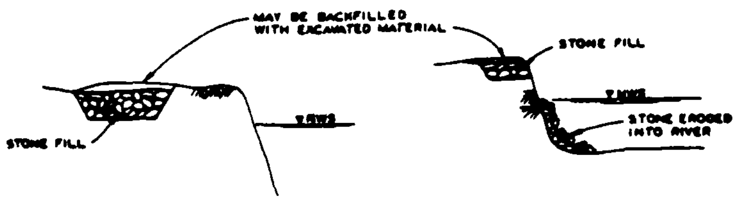
GAVINS POINT DAM TO PONCA, NEBRASKA

TYPICAL BANK PROTECTION SCHEMES

PLATE 0-17

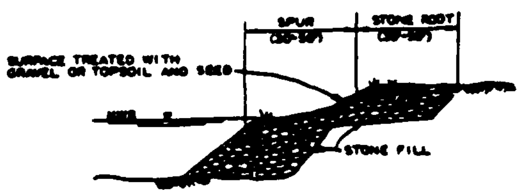


WINDROW REVETMENT



SECTION 1 SECTION 2

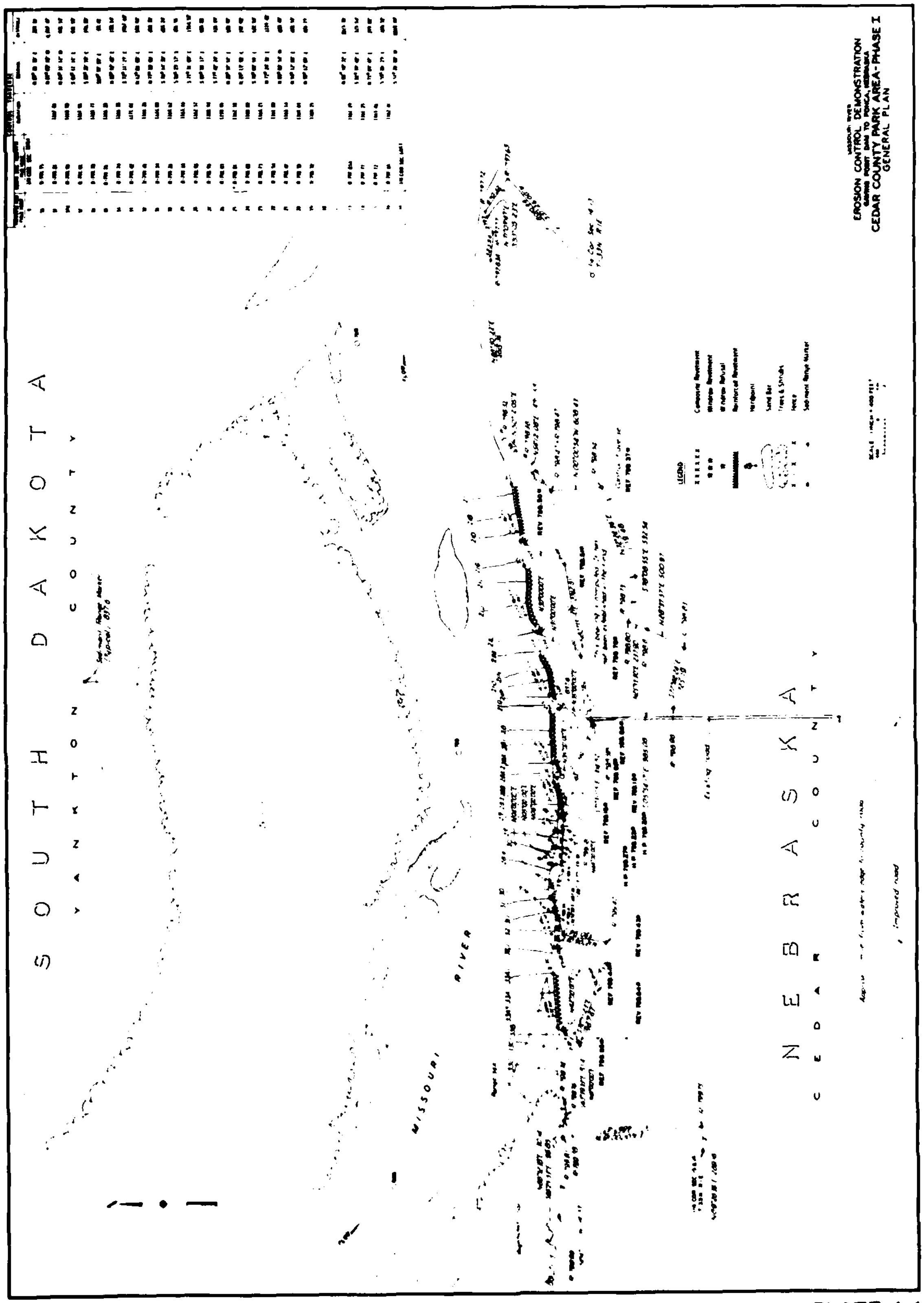
HARD POINT SYSTEM



TYPICAL SECTION

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
TYPICAL BANK PROTECTION SCHEMES

PLATE 0-18



SOUTH DAKOTA
YANKTON COUNTY
NEBRASKA
CEDAR COUNTY
MISSOURI RIVER
LEGEND
EROSION CONTROL DEMONSTRATION
CEDAR COUNTY PARK AREA - PHASE I
GENERAL PLAN

PLATE 1-1

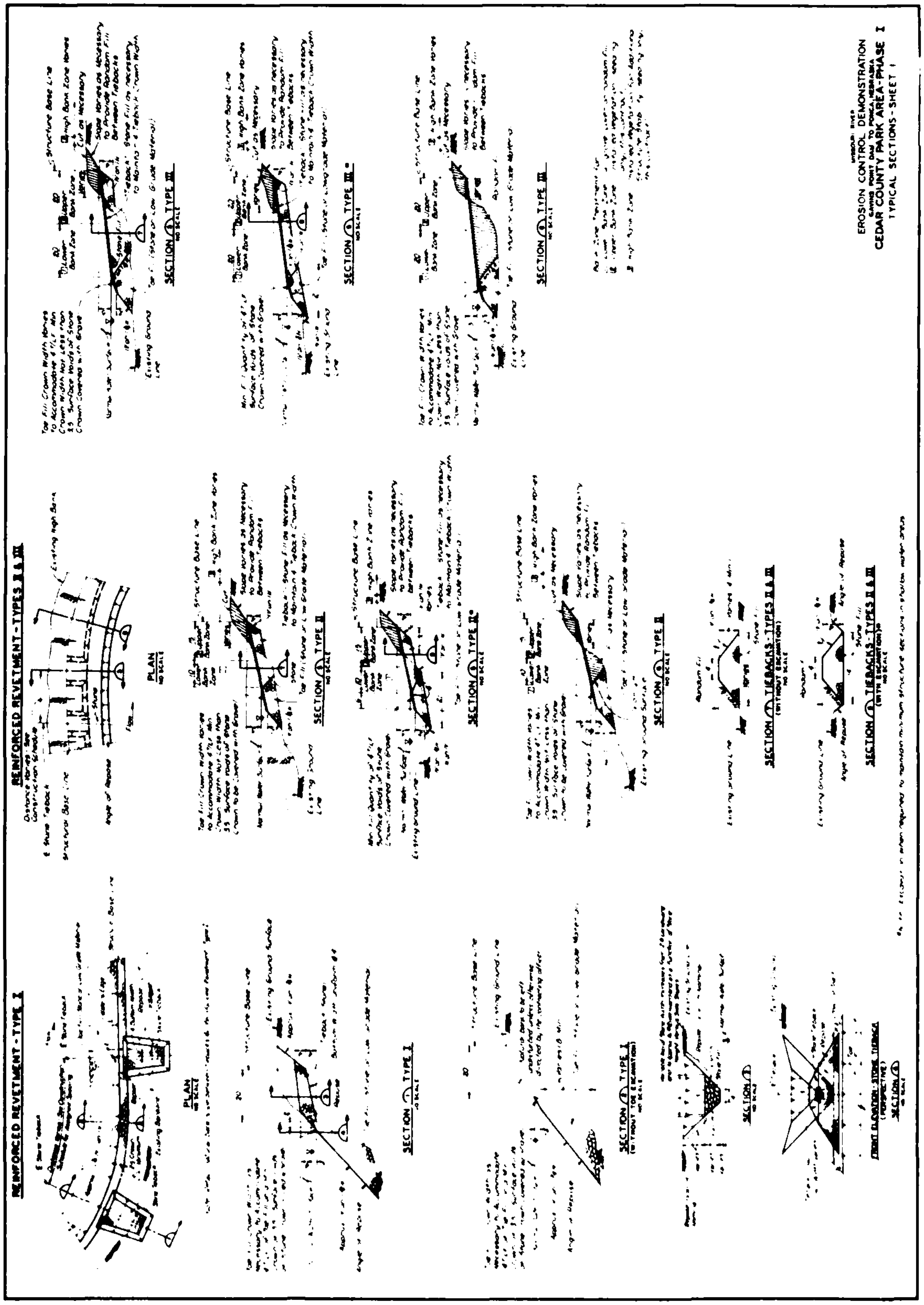

REINFORCED REVETMENT - TYPE I
REINFORCED REVETMENT - TYPES II & III
PLAN
SECTION A TYPE I
SECTION B TYPE II
SECTION TYPE III
EROSION CONTROL DEMONSTRATION
CEDAR COUNTY PARK AREA - PHASE I
TYPICAL SECTIONS - SHEET 1

PLATE 1-2

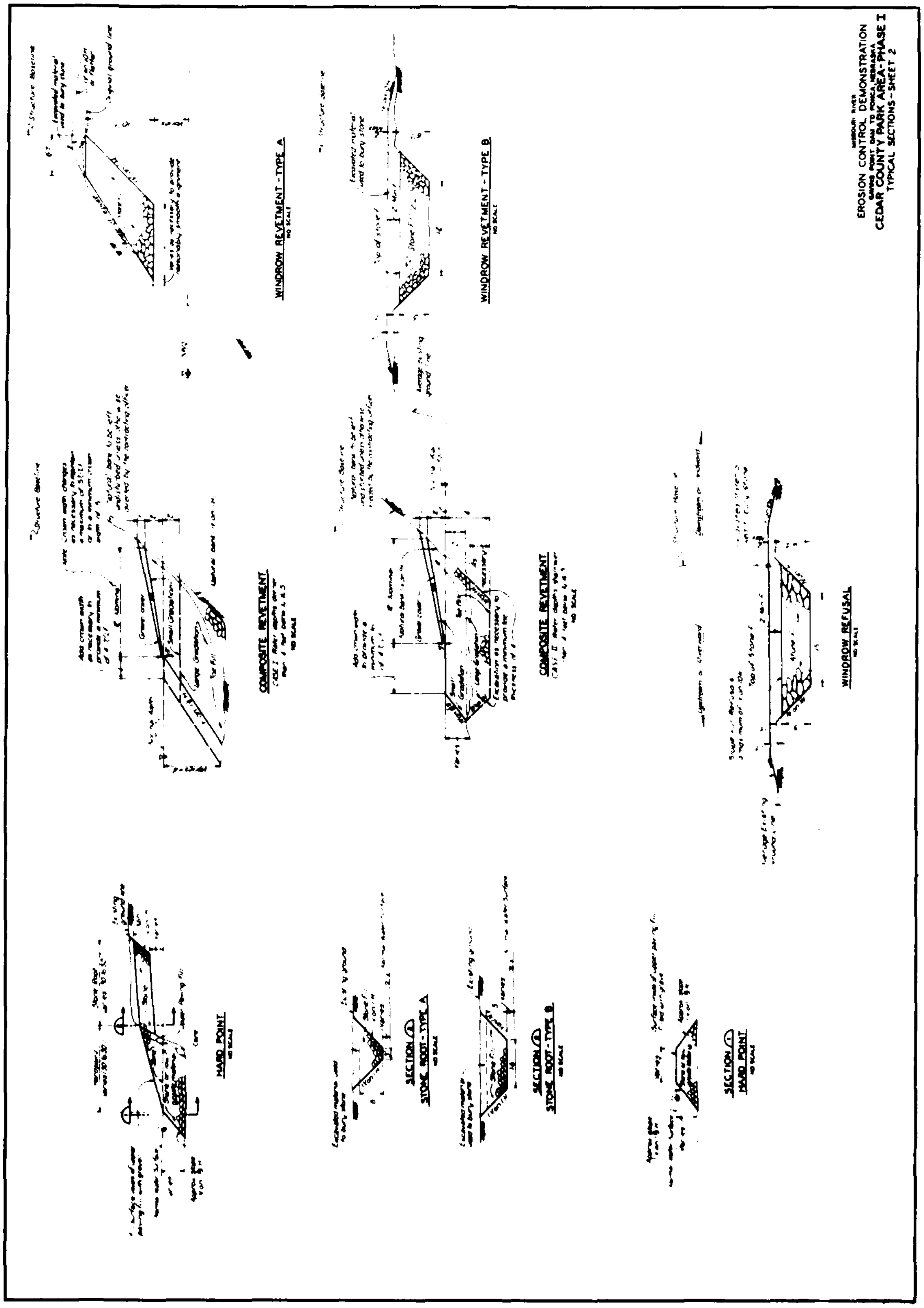
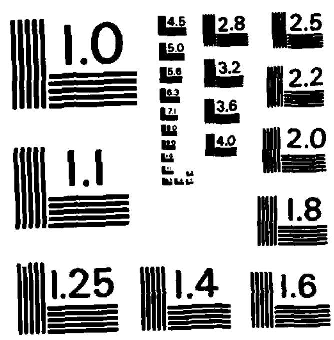

WINDROW REVETMENT - TYPE A
NO SCALE
WINDROW REVETMENT - TYPE B
NO SCALE
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
CEDAR COUNTY PARK AREA - PHASE I
TYPICAL SECTIONS - SHEET 2
COMPOSITE REVETMENT
NO SCALE
COMPOSITE REVETMENT
NO SCALE
WINDROW REFUSAL
NO SCALE
HARD POINT
NO SCALE
SECTION
STONE ROOT - TYPE A
NO SCALE
SECTION
STONE ROOT - TYPE B
NO SCALE
SECTION
HARD POINT
NO SCALE

PLATE 1-3

AD-A121 136 THE STREAMBANK EROSION CONTROL EVALUATION AND DEMONSTRATION ACT OF 1974 S..(U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS HYDRA.. 3/4

UNCLASSIFIED M P KEOWN ET AL. DEC 81 F/G 13/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

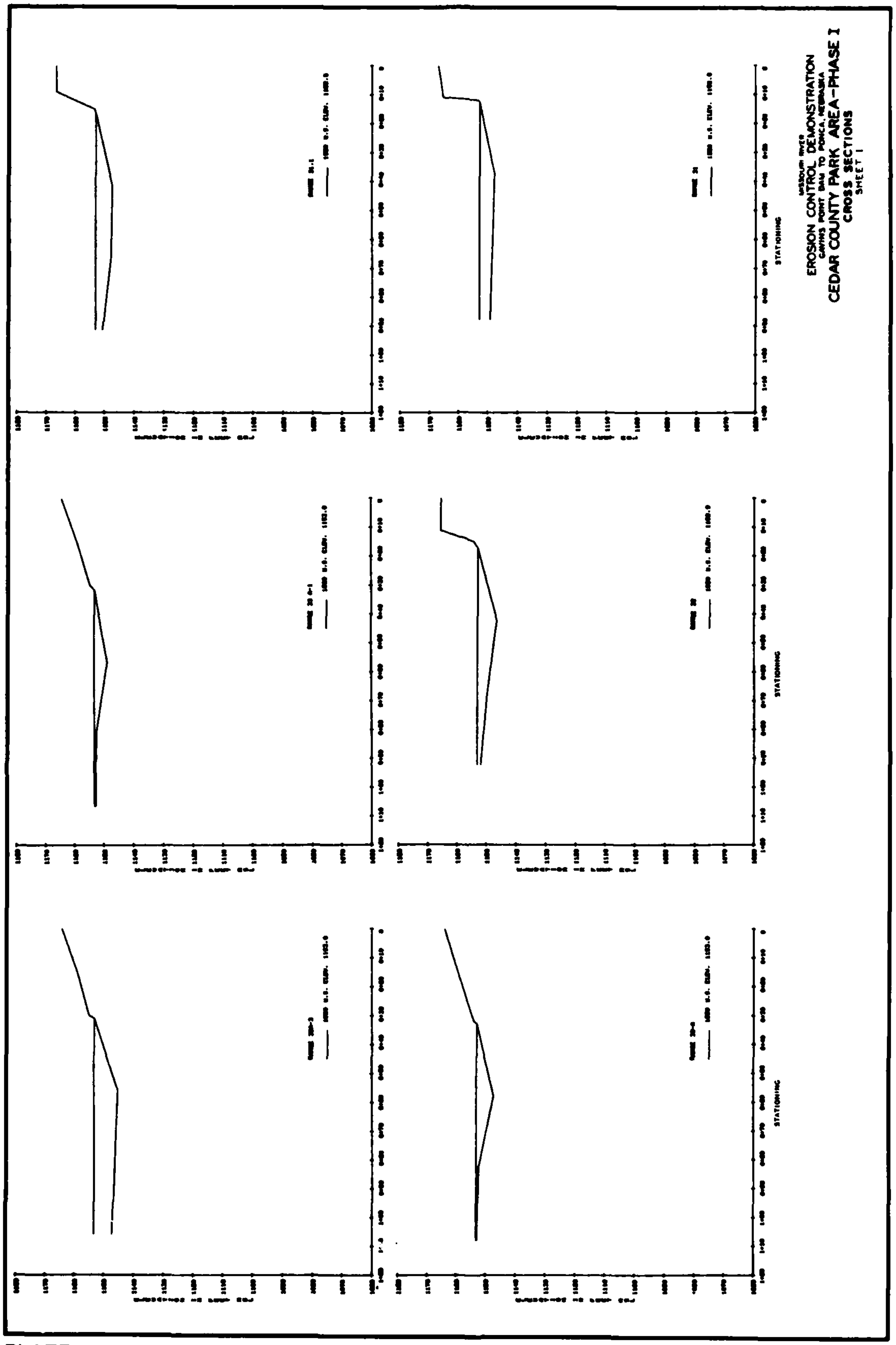

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
CEDAR COUNTY PARK AREA-PHASE I
CROSS SECTIONS
SHEET 1
STATIONING

PLATE 1-4

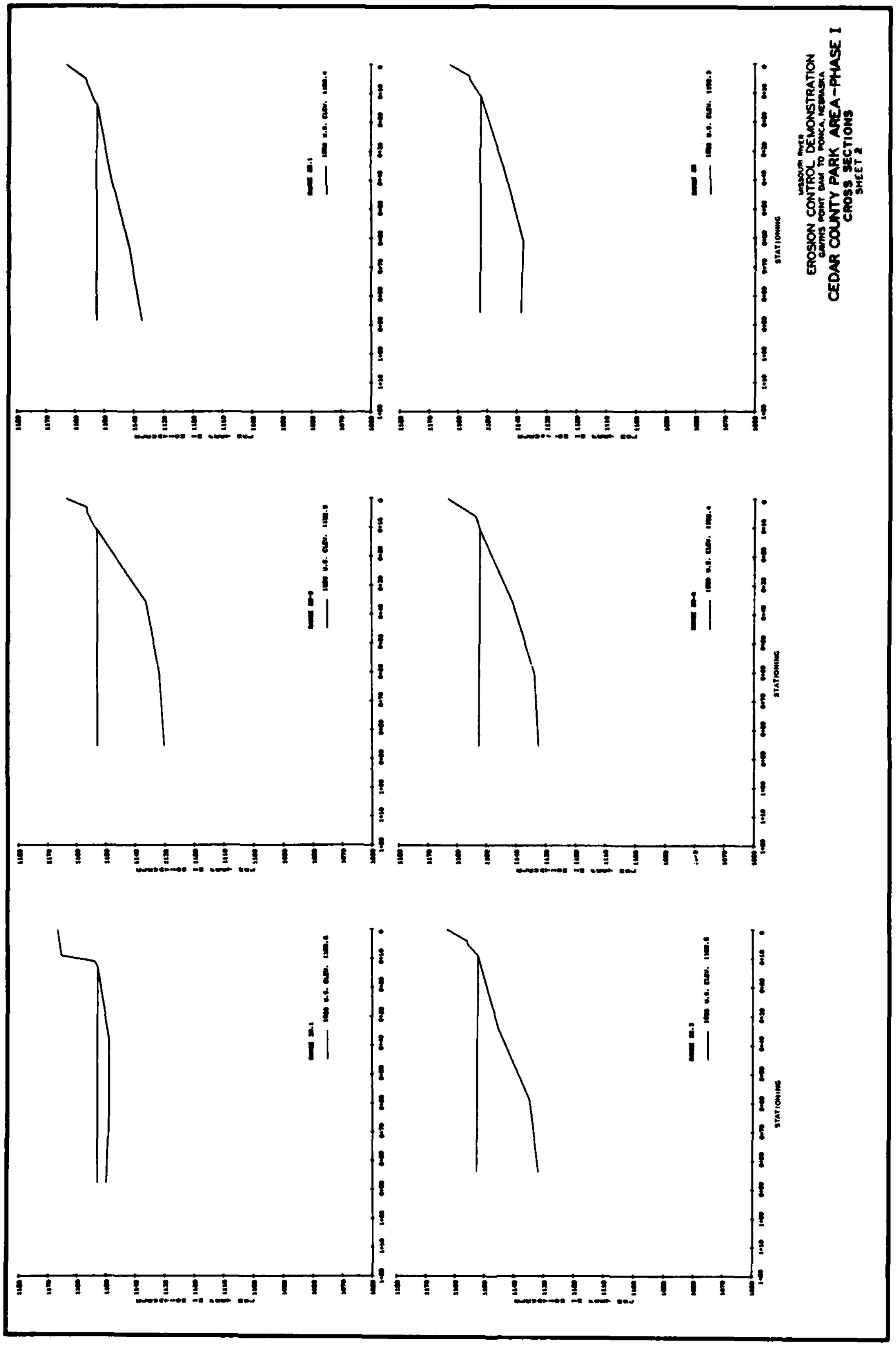

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
CEDAR COUNTY PARK AREA–PHASE I
CROSS SECTIONS
SHEET 2
STATIONING

PLATE 1-5

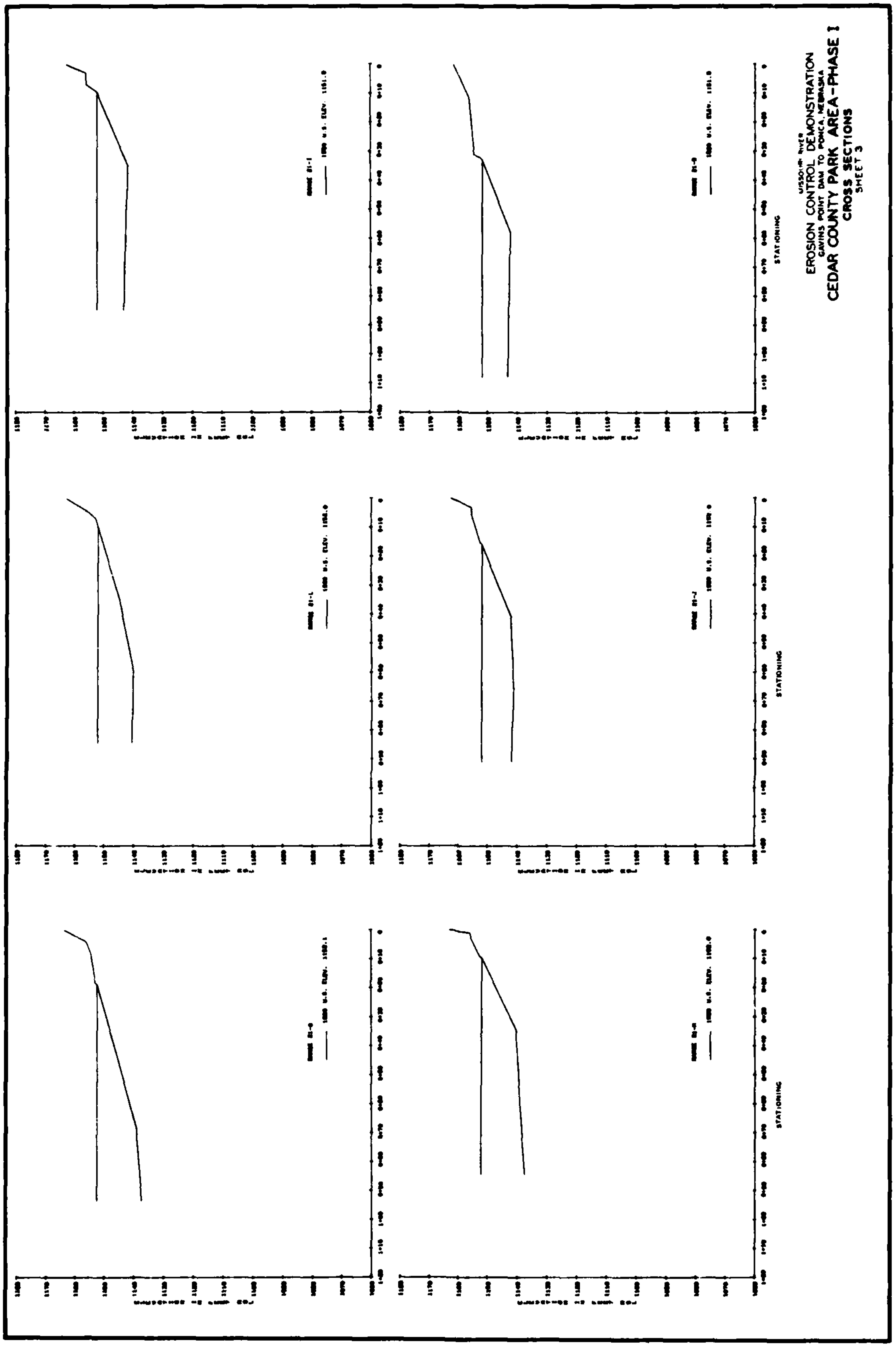
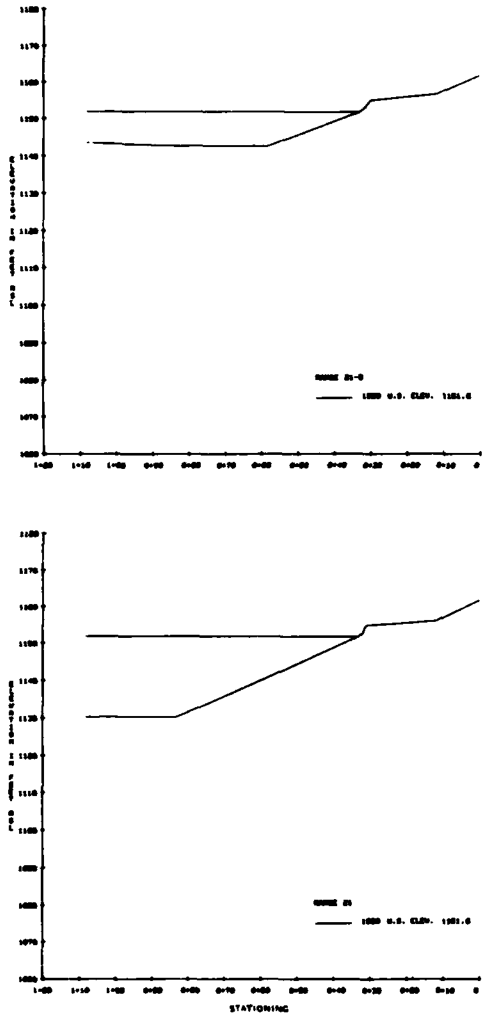

STATIONING
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
CEDAR COUNTY PARK AREA-PHASE I
CROSS SECTIONS
SHEET 3

PLATE 1-6



MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
CEDAR COUNTY PARK AREA-PHASE I
CROSS SECTIONS
SHEET 4

PLATE 1-7

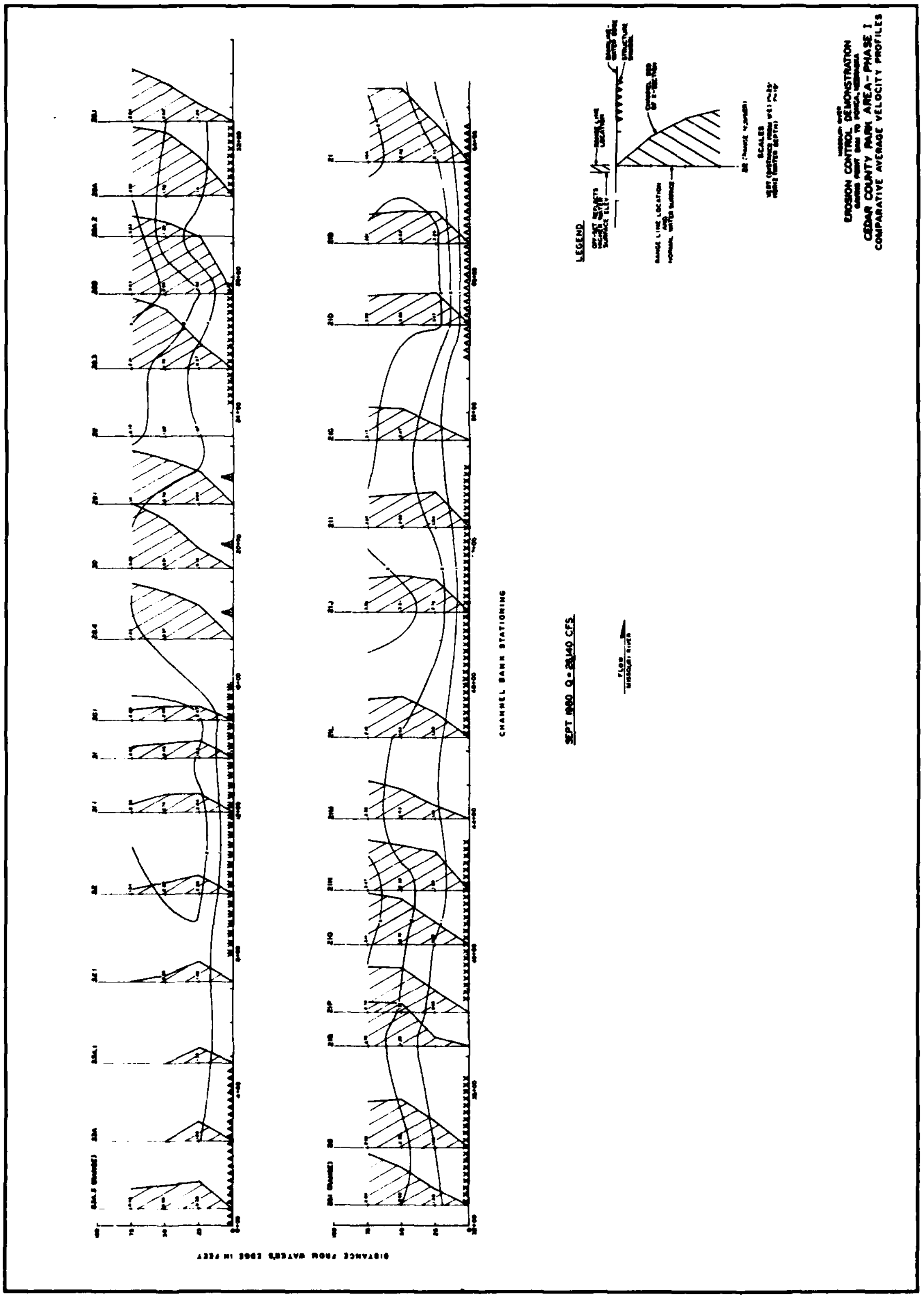

LEGEND
SCALES
EROSION CONTROL DEMONSTRATION
CEDAR COUNTY PARK AREA - PHASE I
COMPARATIVE AVERAGE VELOCITY PROFILES
SEPT 1980 Q = 28,140 CFS
CHANNEL BANK STATIONING
DISTANCE FROM WATER'S EDGE IN FEET

PLATE 1-8

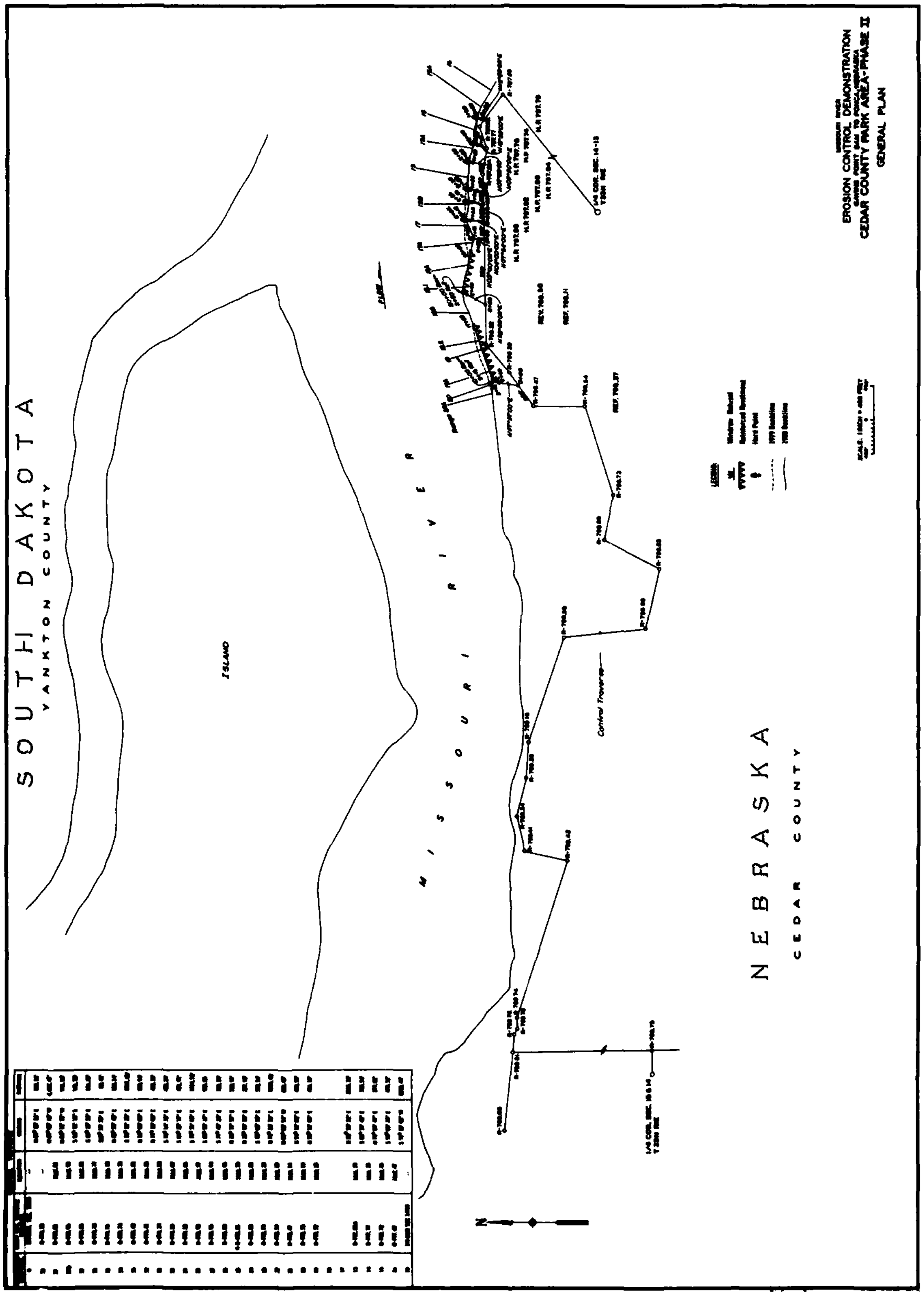

SOUTH DAKOTA
YANKTON COUNTY
ISLAND
MISSOURI RIVER
Control Traverse
NEBRASKA
CEDAR COUNTY
EROSION CONTROL DEMONSTRATION
CEDAR COUNTY PARK AREA - PHASE II
GENERAL PLAN

PLATE 2-1

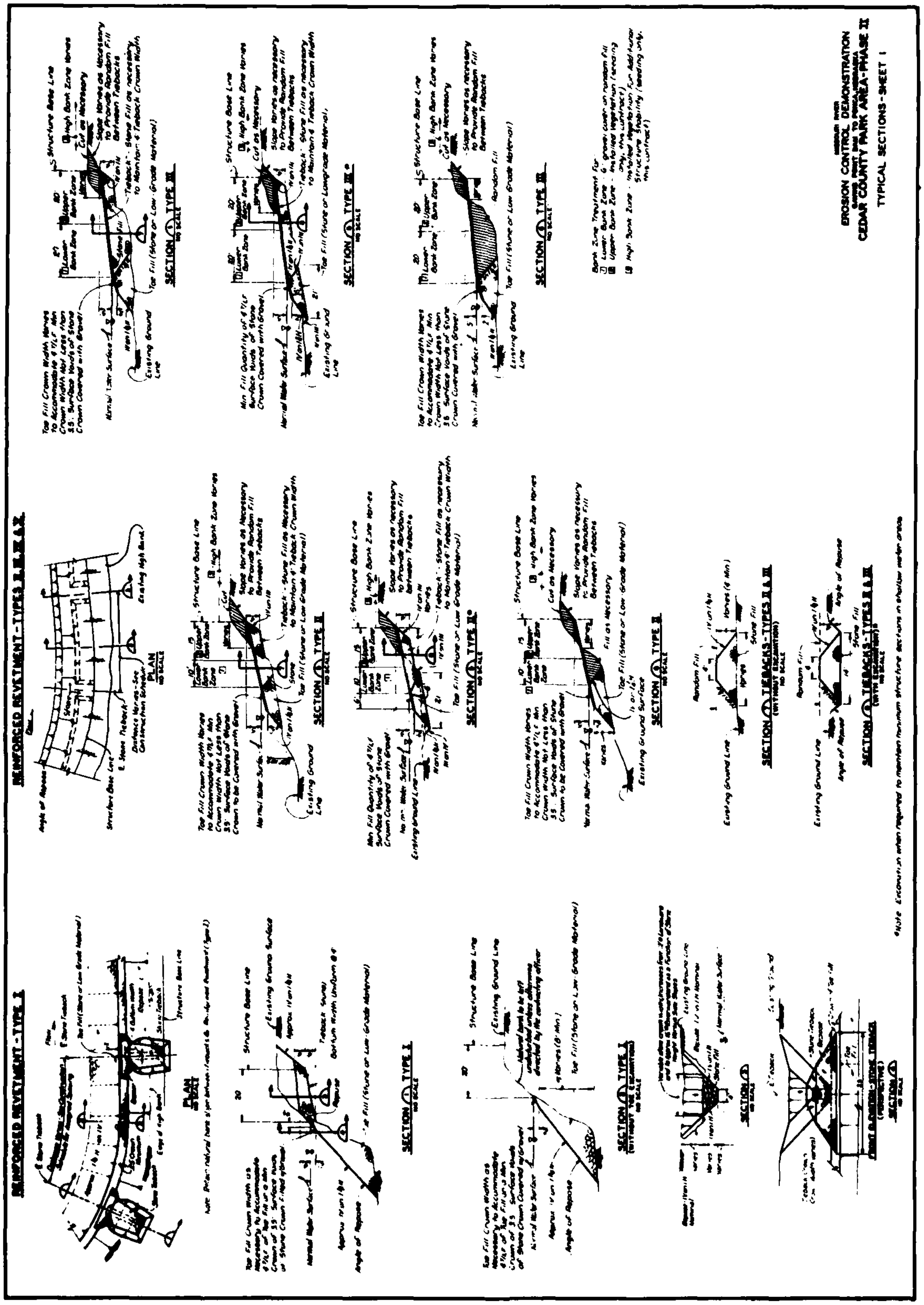


PLATE 2-2

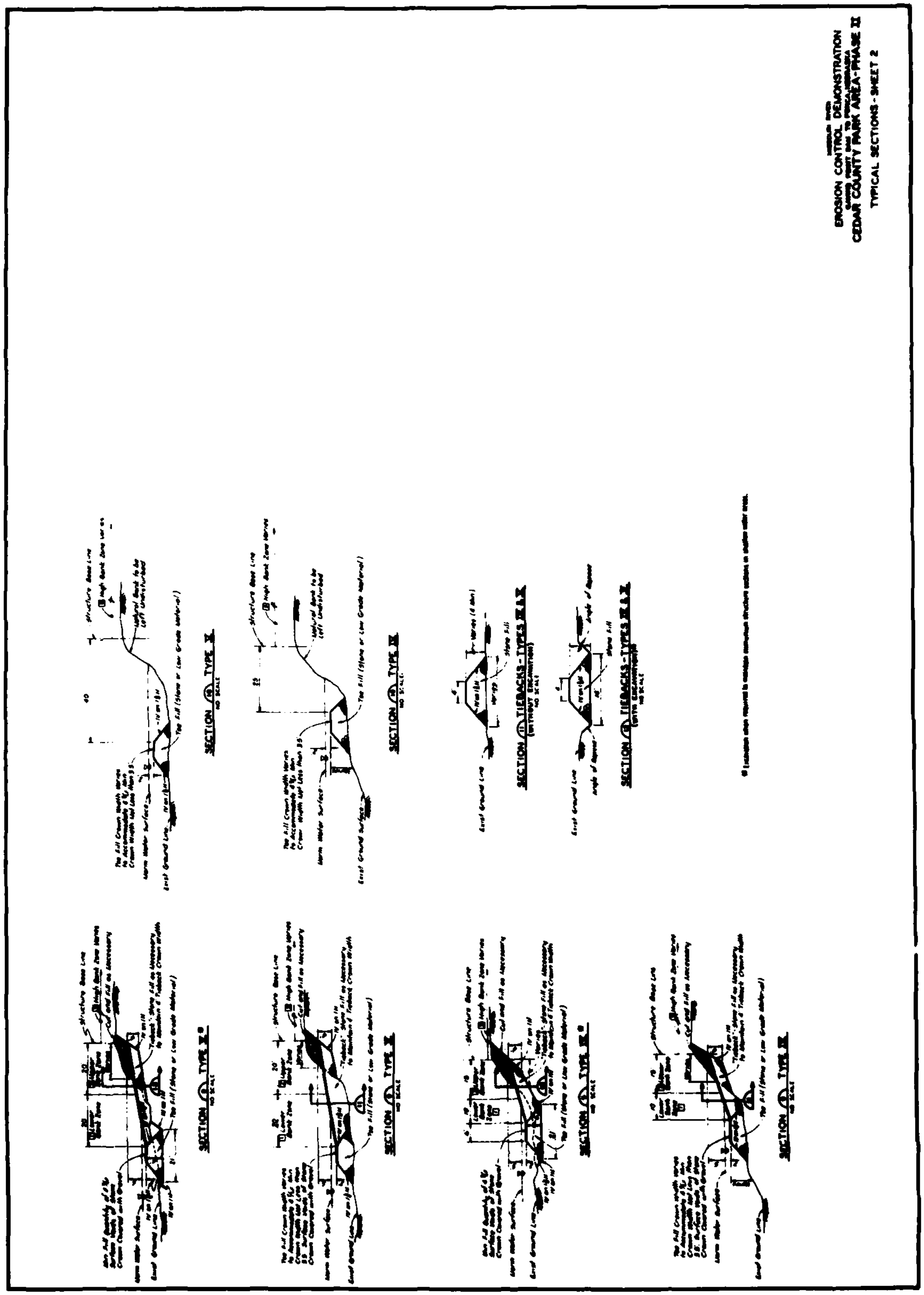

EROSION CONTROL DEMONSTRATION
CEDAR COUNTY PARK AREA - PHASE II
TYPICAL SECTIONS - SHEET 2
SECTION A TYPE V
SECTION A TYPE X
SECTION A TYPE VI
SECTION A TYPE IX
SECTION A TYPE VII
SECTION A TIEBACKS - TYPES III & X
SECTION A TYPE VIII
SECTION A TIEBACKS - TYPES III & X

PLATE 2-3

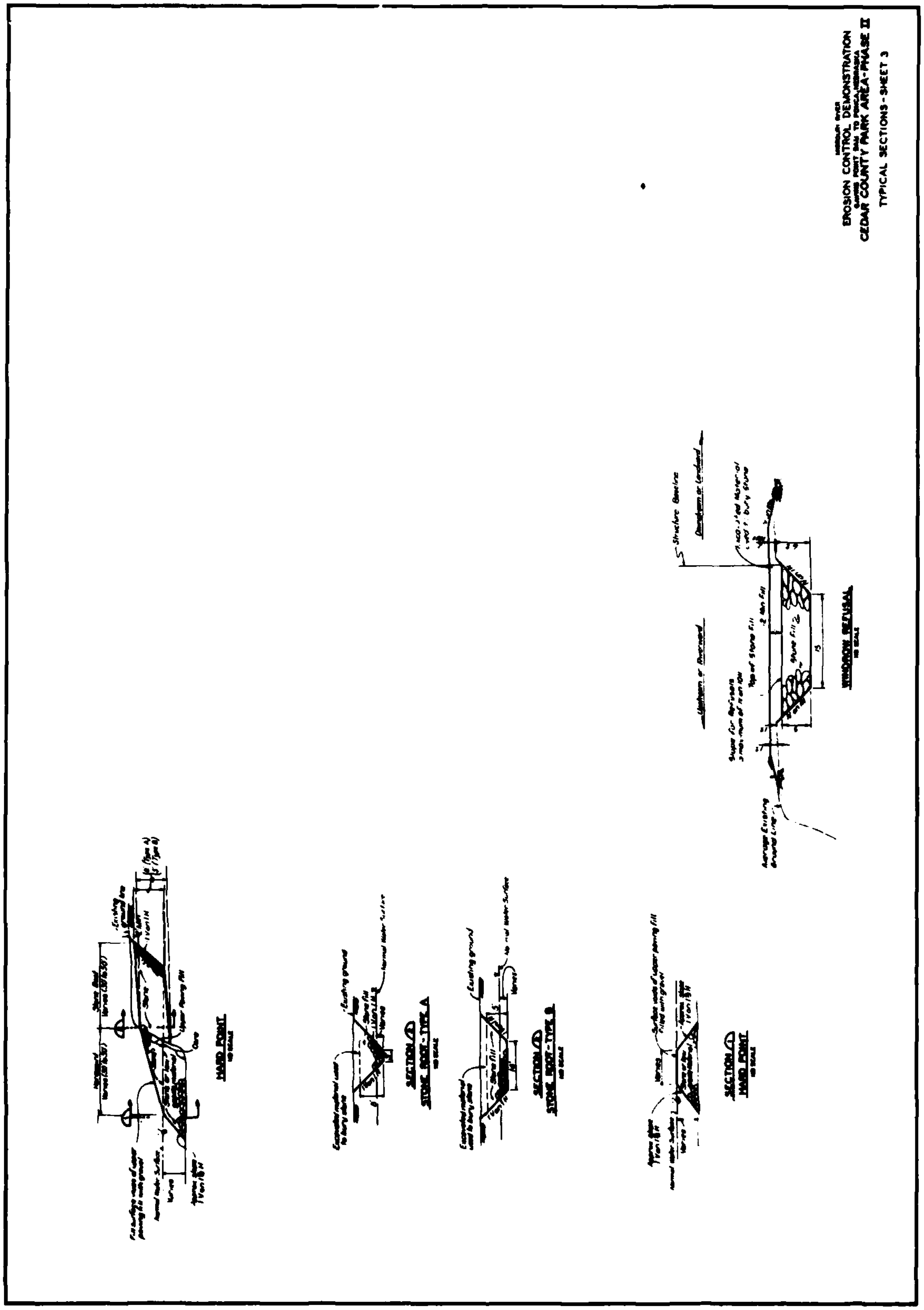

EROSION CONTROL DEMONSTRATION
CEDAR COUNTY PARK AREA - PHASE II
TYPICAL SECTIONS - SHEET 3
WINDROW REFUSAL
HARD POINT

PLATE 2-4

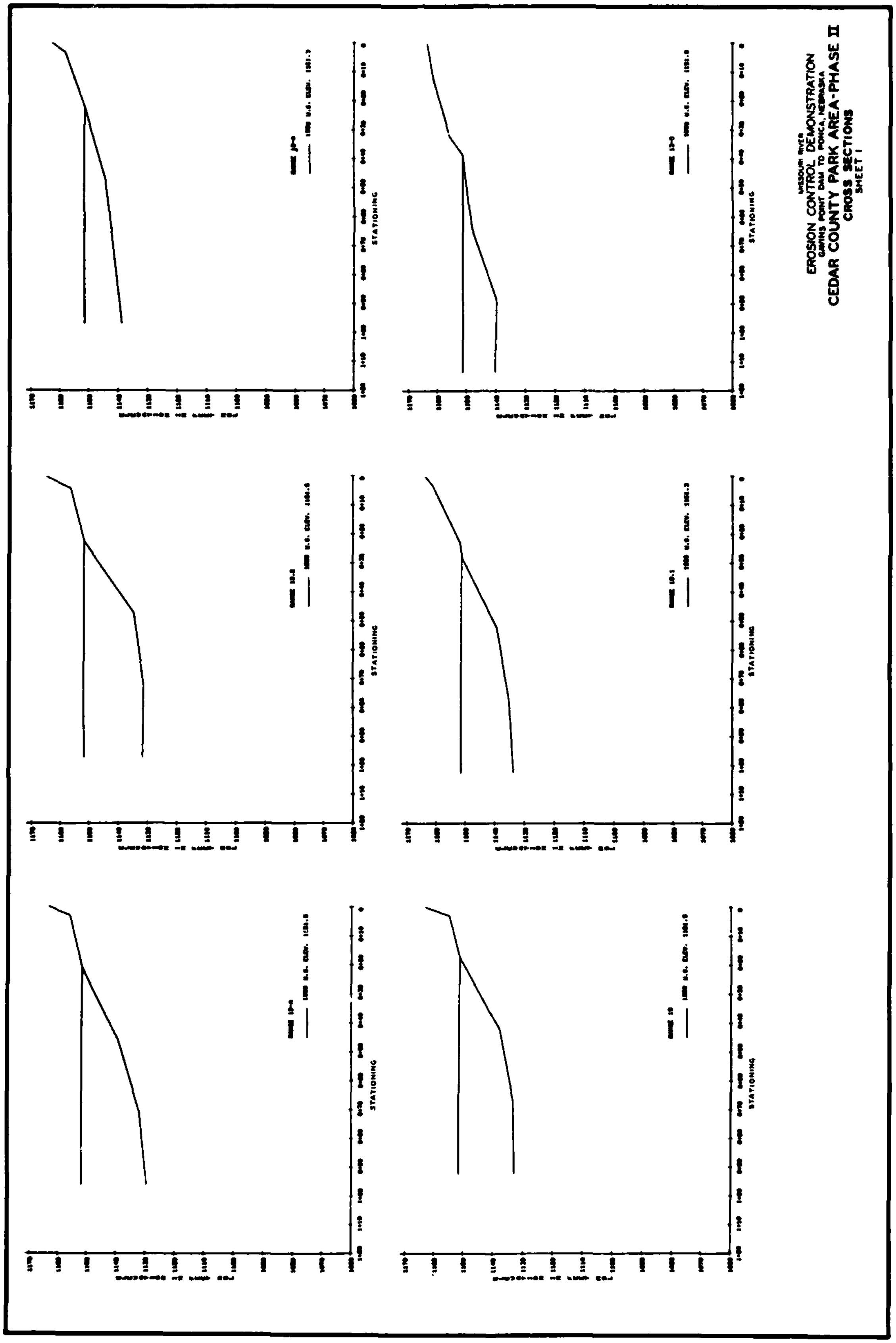

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
CEDAR COUNTY PARK AREA-PHASE II
CROSS SECTIONS
SHEET 1
STATIONING

PLATE 2-5

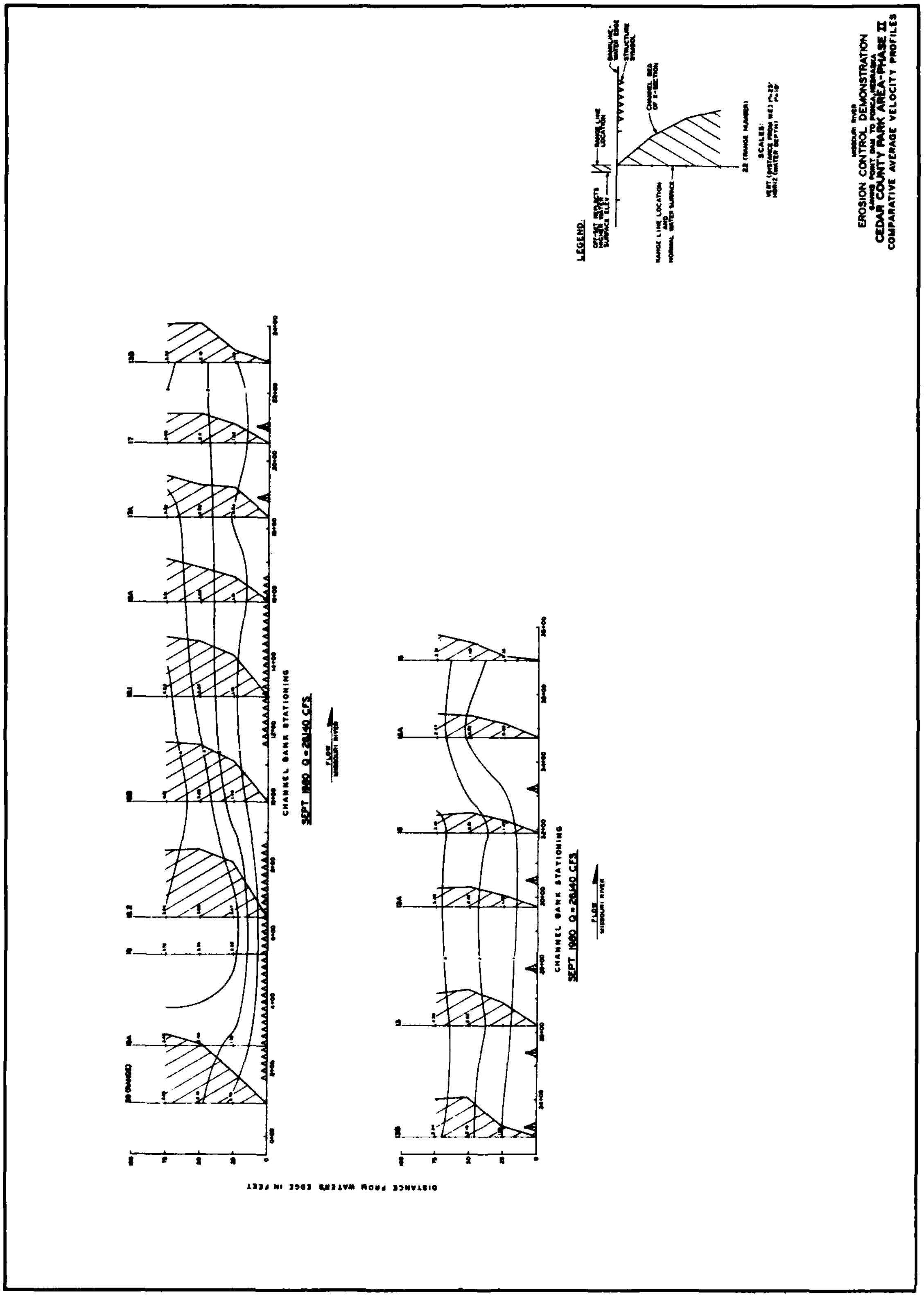

EROSION CONTROL DEMONSTRATION
CEDAR COUNTY PARK AREA-PHASE II
COMPARATIVE AVERAGE VELOCITY PROFILES
LEGEND:
CHANNEL BANK STATIONING
SEPT 1980 Q=28,140 CFS
DISTANCE FROM WATERS EDGE IN FEET

PLATE 2-6

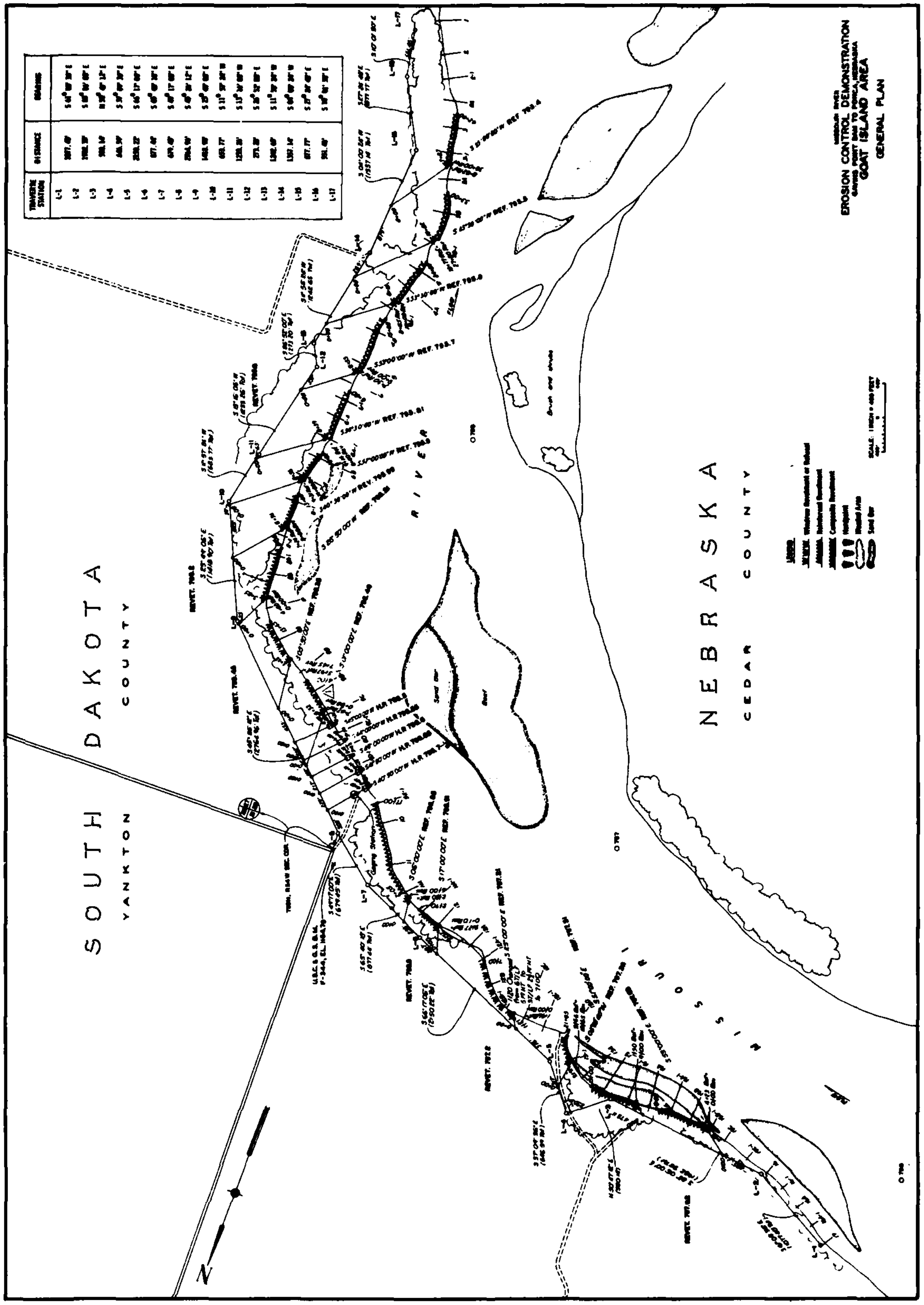

SOUTH DAKOTA
YANKTON COUNTY
NEBRASKA
CEDAR COUNTY
RIVER
EROSION CONTROL DEMONSTRATION
GOAT ISLAND AREA
GENERAL PLAN

PLATE 3-1

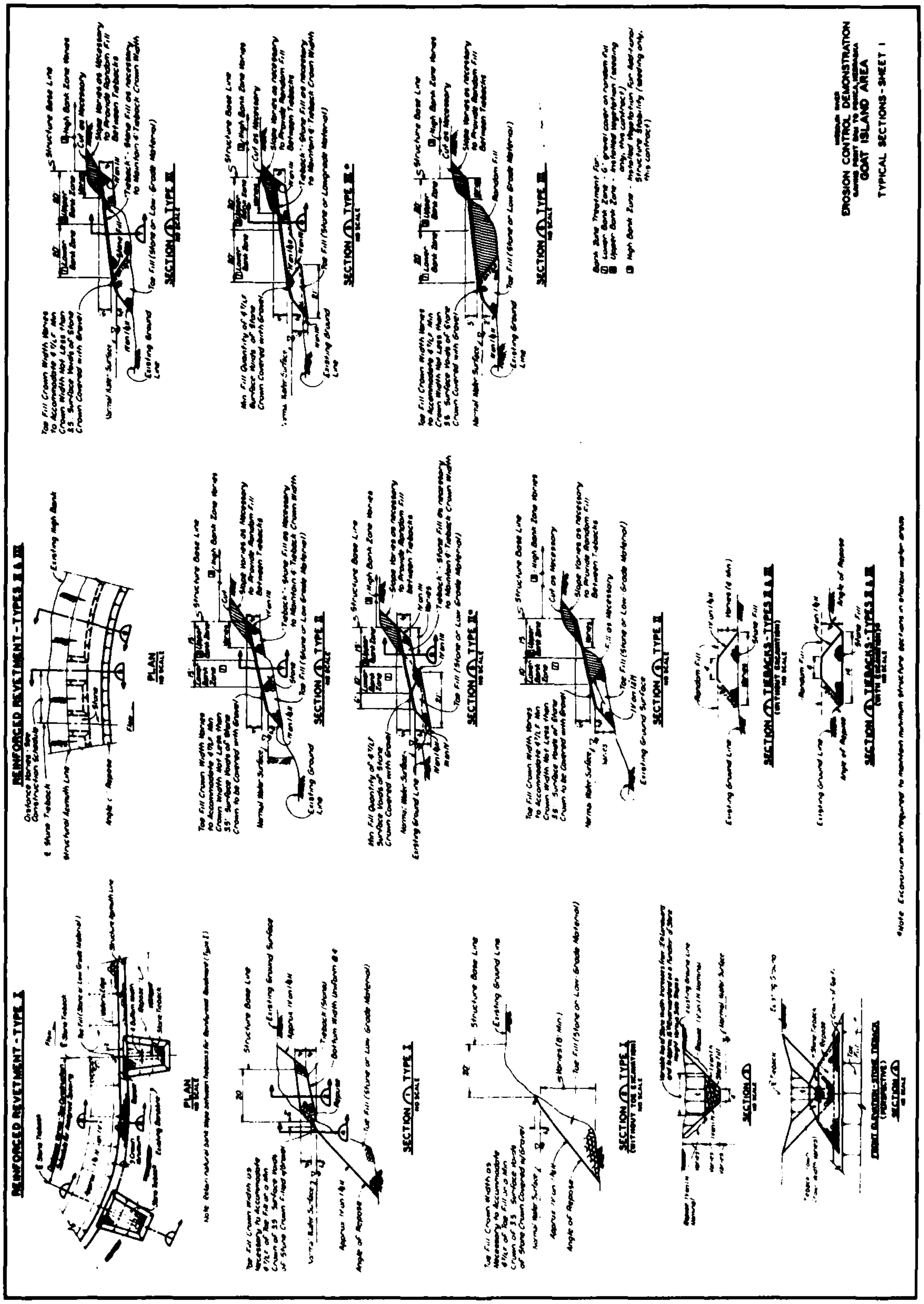

EROSION CONTROL DEMONSTRATION
GOAT ISLAND AREA
TYPICAL SECTIONS - SHEET 1

PLATE 3-2

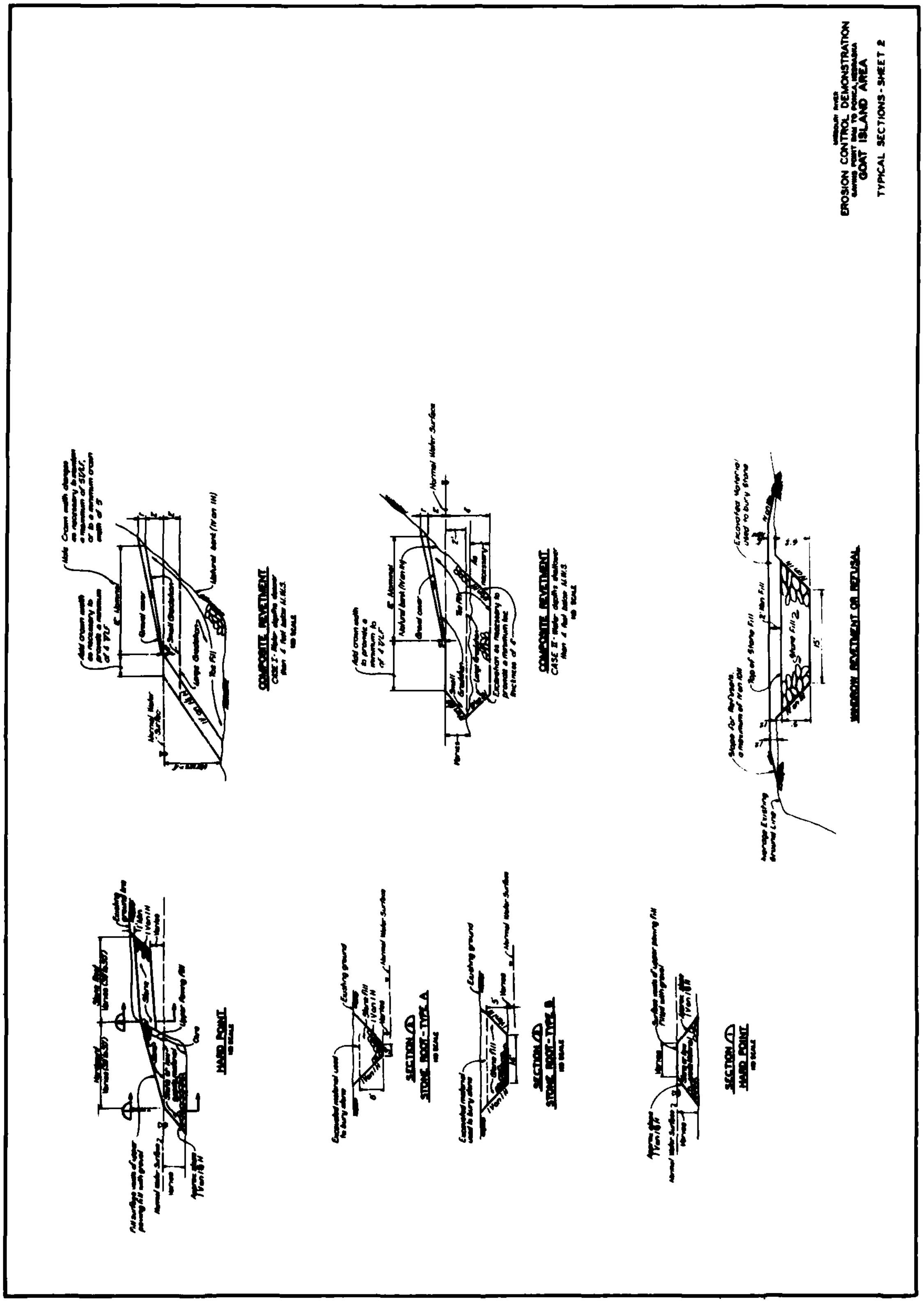

HARD POINT
NO SCALE
COMPOSITE REVETMENT
CASE I - Water depths deeper than 4 feet below N.W.S.
NO SCALE
SECTION A
STONE ROOT - TYPE A
NO SCALE
SECTION B
STONE ROOT - TYPE B
NO SCALE
COMPOSITE REVETMENT
CASE II - Water depths shallower than 4 feet below N.W.S.
NO SCALE
SECTION
HARD POINT
NO SCALE
WINDROW REVETMENT OR REFUSAL
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
GOAT ISLAND AREA
TYPICAL SECTIONS - SHEET 2

PLATE 3-3

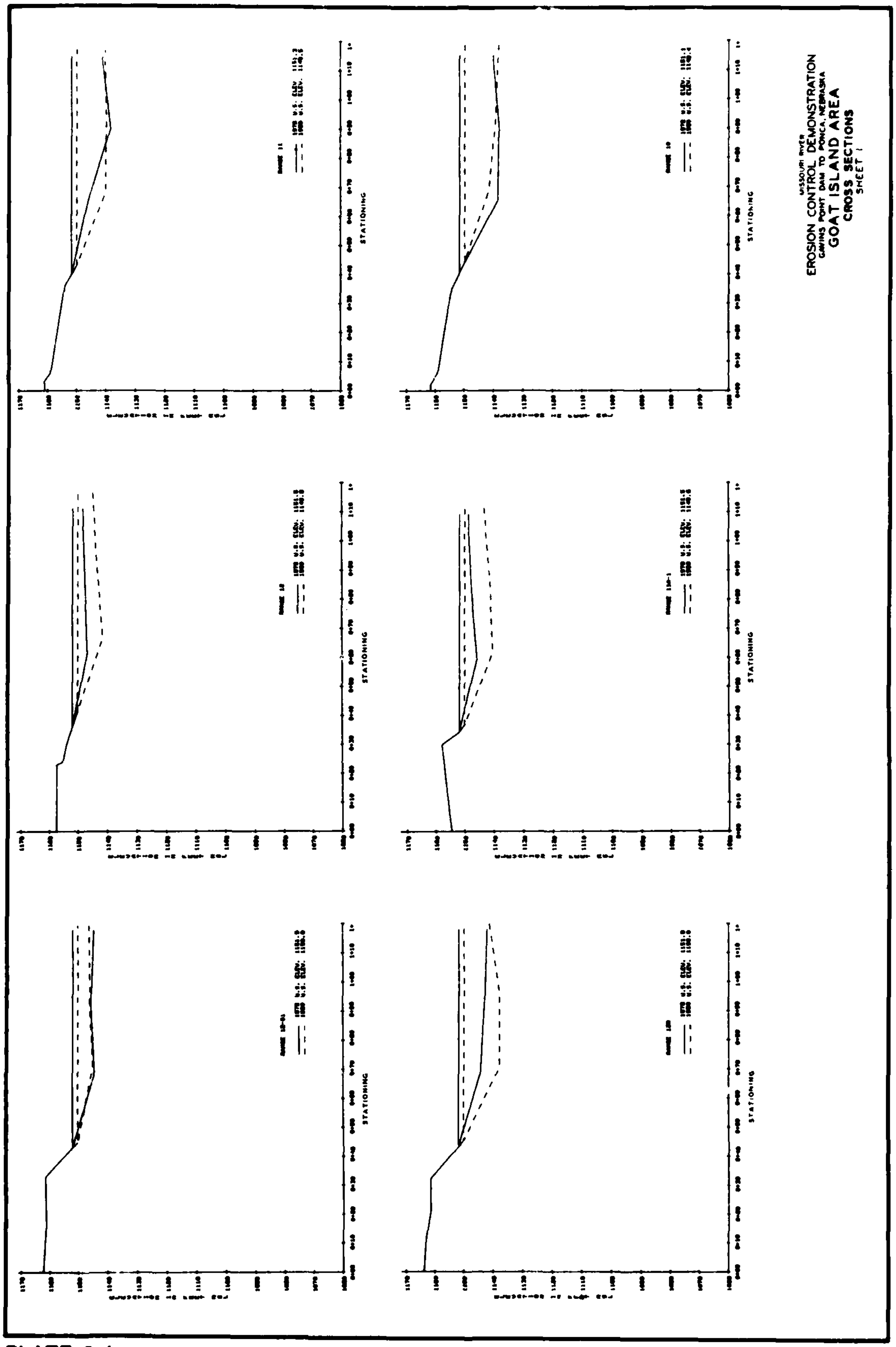

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
GOAT ISLAND AREA
CROSS SECTIONS
SHEET 1
STATIONING

PLATE 3-4

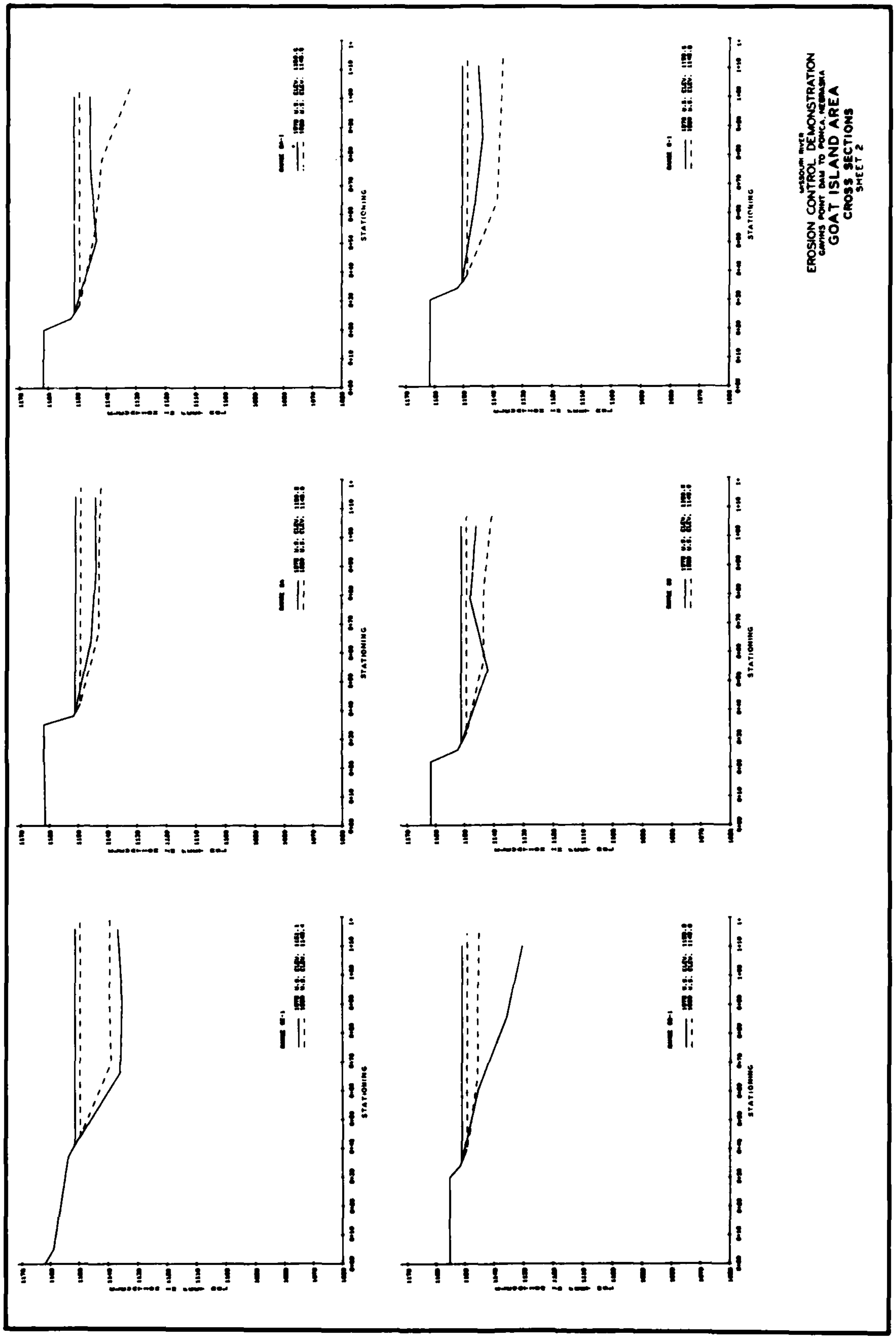

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
GOAT ISLAND AREA
CROSS SECTIONS
SHEET 2
STATIONING

PLATE 3-5

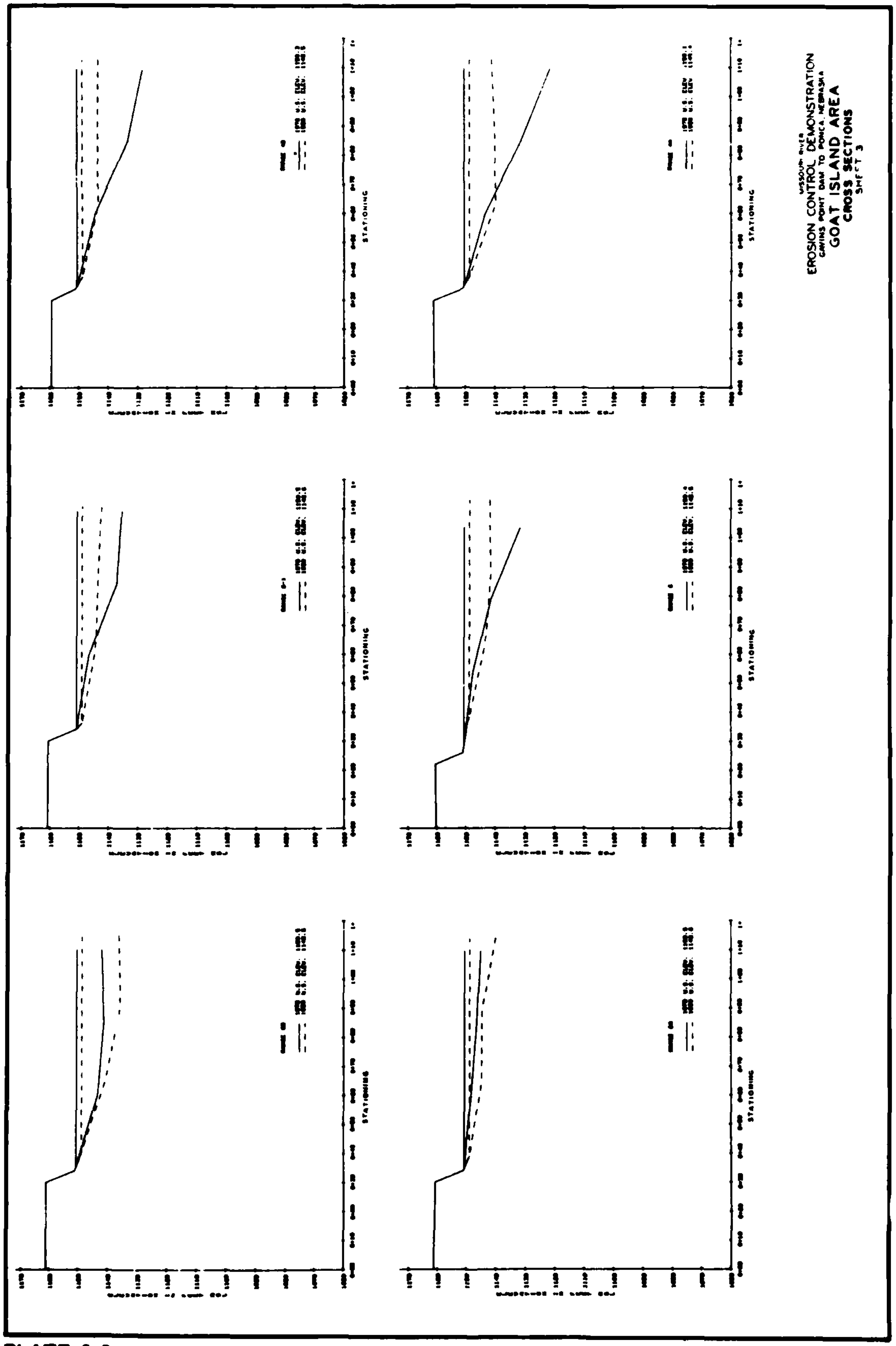
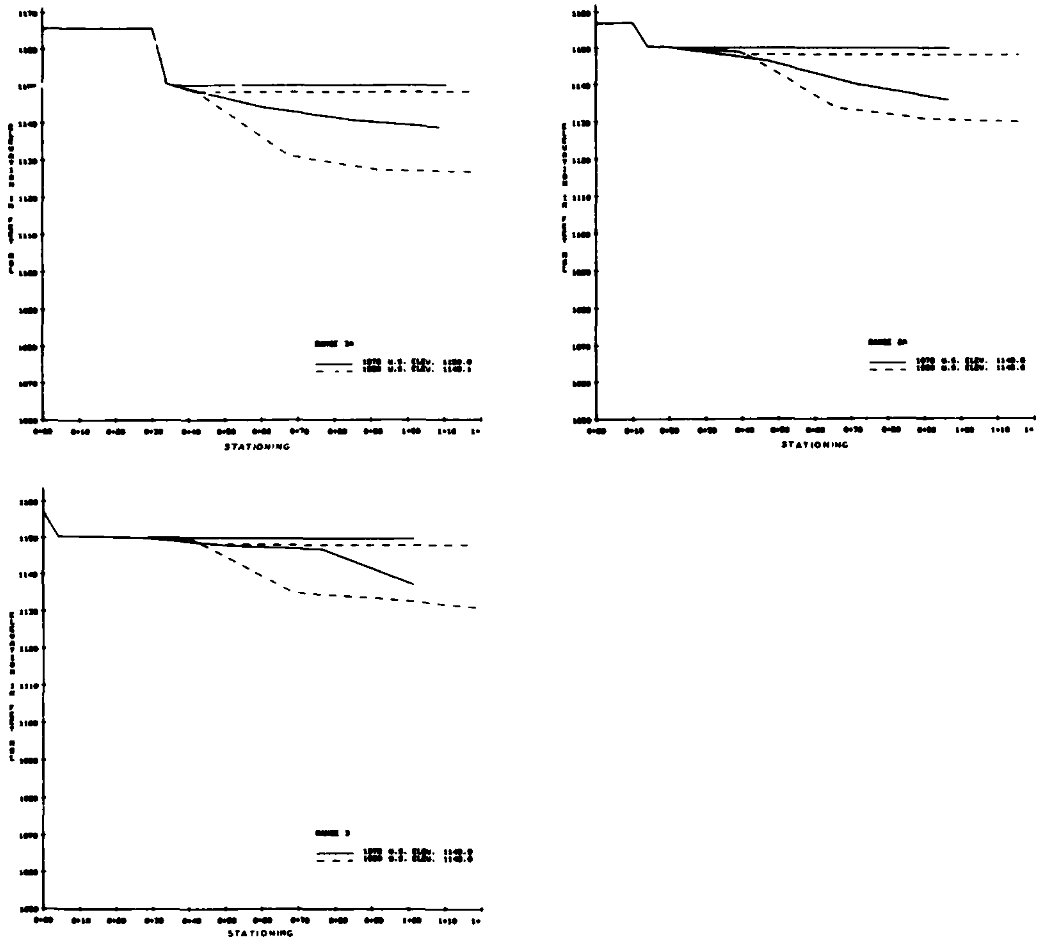

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
GOAT ISLAND AREA
CROSS SECTIONS
SHEET 3
STATIONING

PLATE 3-6



MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
GOAT ISLAND AREA
CROSS SECTIONS
SHEET 4

PLATE 3-7

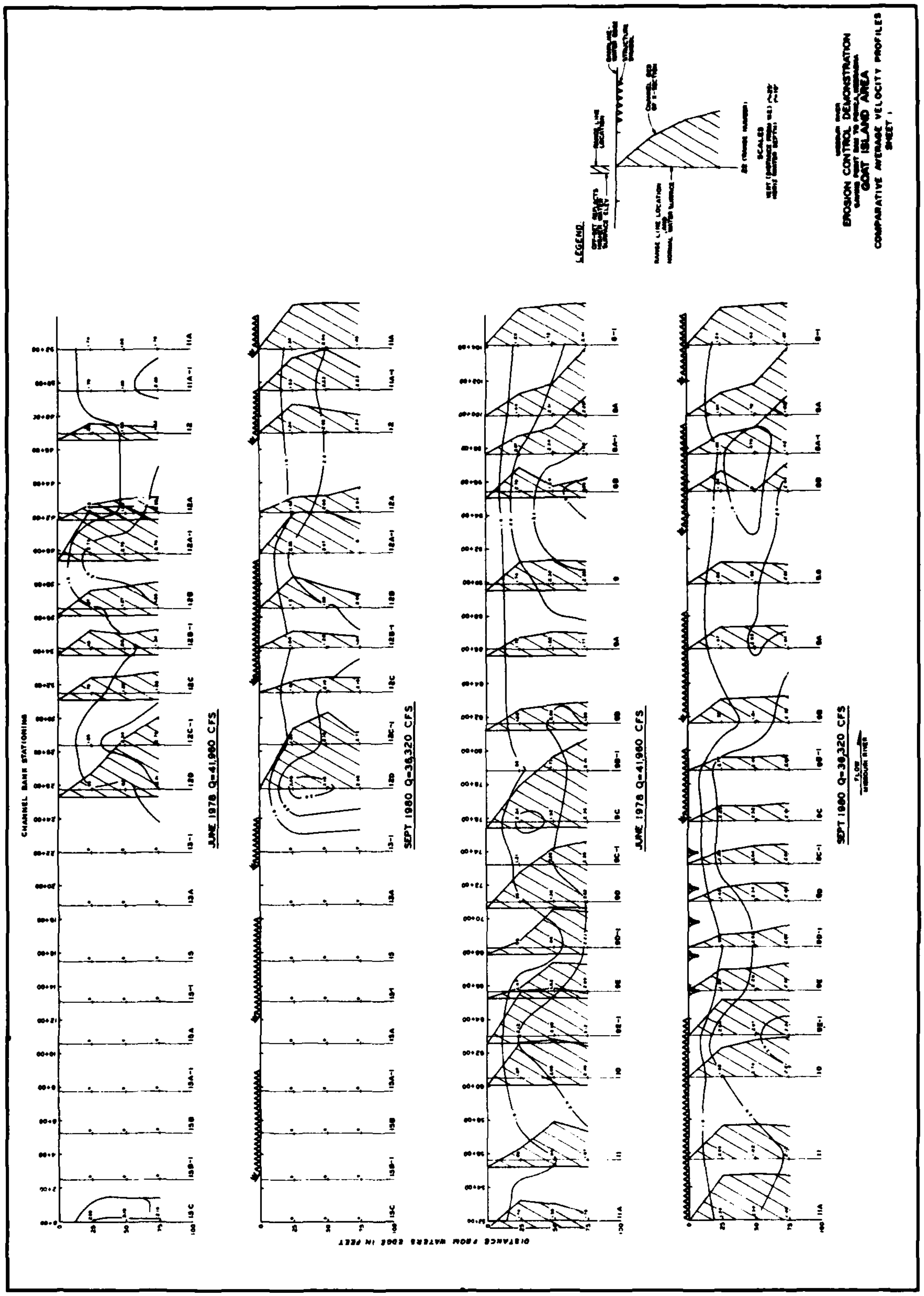
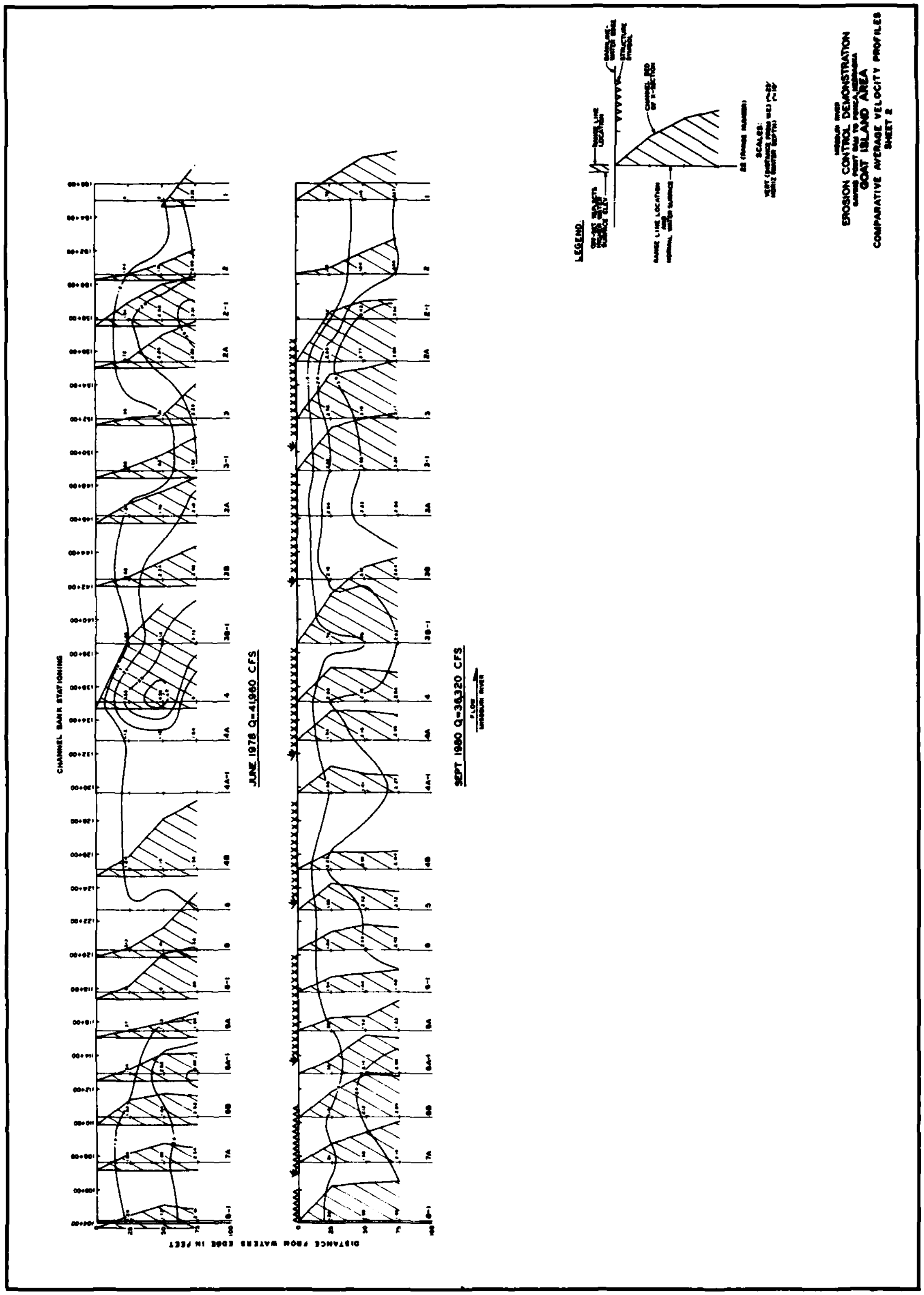

EROSION CONTROL DEMONSTRATION
GOAT ISLAND AREA
COMPARATIVE AVERAGE VELOCITY PROFILES
SHEET 1
LEGEND
SCALES
CHANNEL BANK STATIONING
DISTANCE FROM WATERS EDGE IN FEET
JUNE 1978 Q=41,960 CFS
SEPT 1980 Q=36,320 CFS
JUNE 1978 Q=41,960 CFS
SEPT 1980 Q=36,320 CFS

PLATE 3-8



CHANNEL BANK STATIONING
DISTANCE FROM WATERS EDGE IN FEET
JUNE 1978 Q=41,960 CFS
SEPT 1980 Q=36,320 CFS
FLOW
LEGEND
SCALES:
EROSION CONTROL DEMONSTRATION
GOAT ISLAND AREA
COMPARATIVE AVERAGE VELOCITY PROFILES
SHEET 2

PLATE 3-9

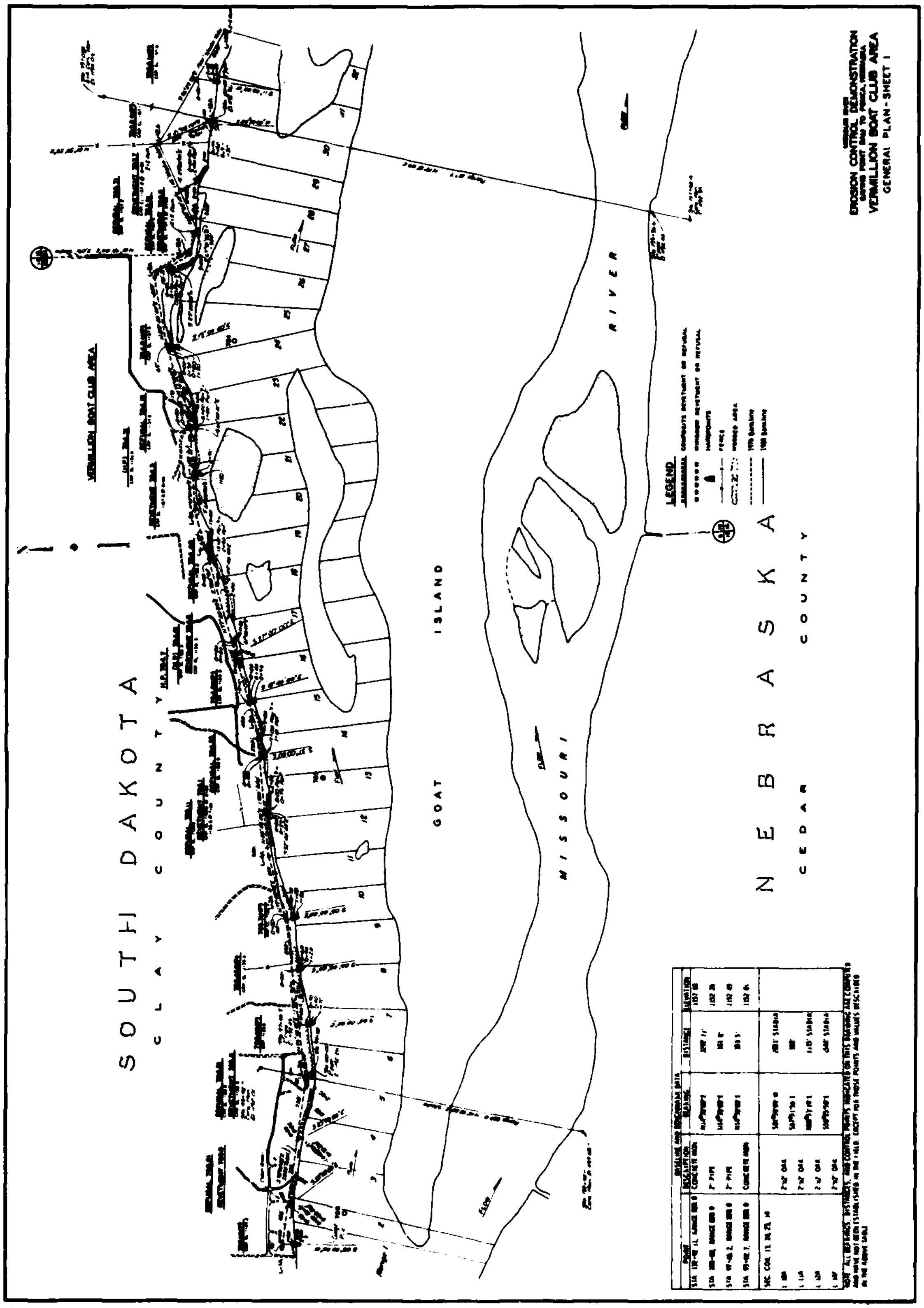

SOUTH DAKOTA
CLAY COUNTY
GOAT ISLAND
MISSOURI RIVER
NEBRASKA
CEDAR COUNTY
VERMILLION BOAT CLUB AREA
LEGEND
EROSION CONTROL DEMONSTRATION
VERMILLION BOAT CLUB AREA
GENERAL PLAN - SHEET 1

PLATE 4-1

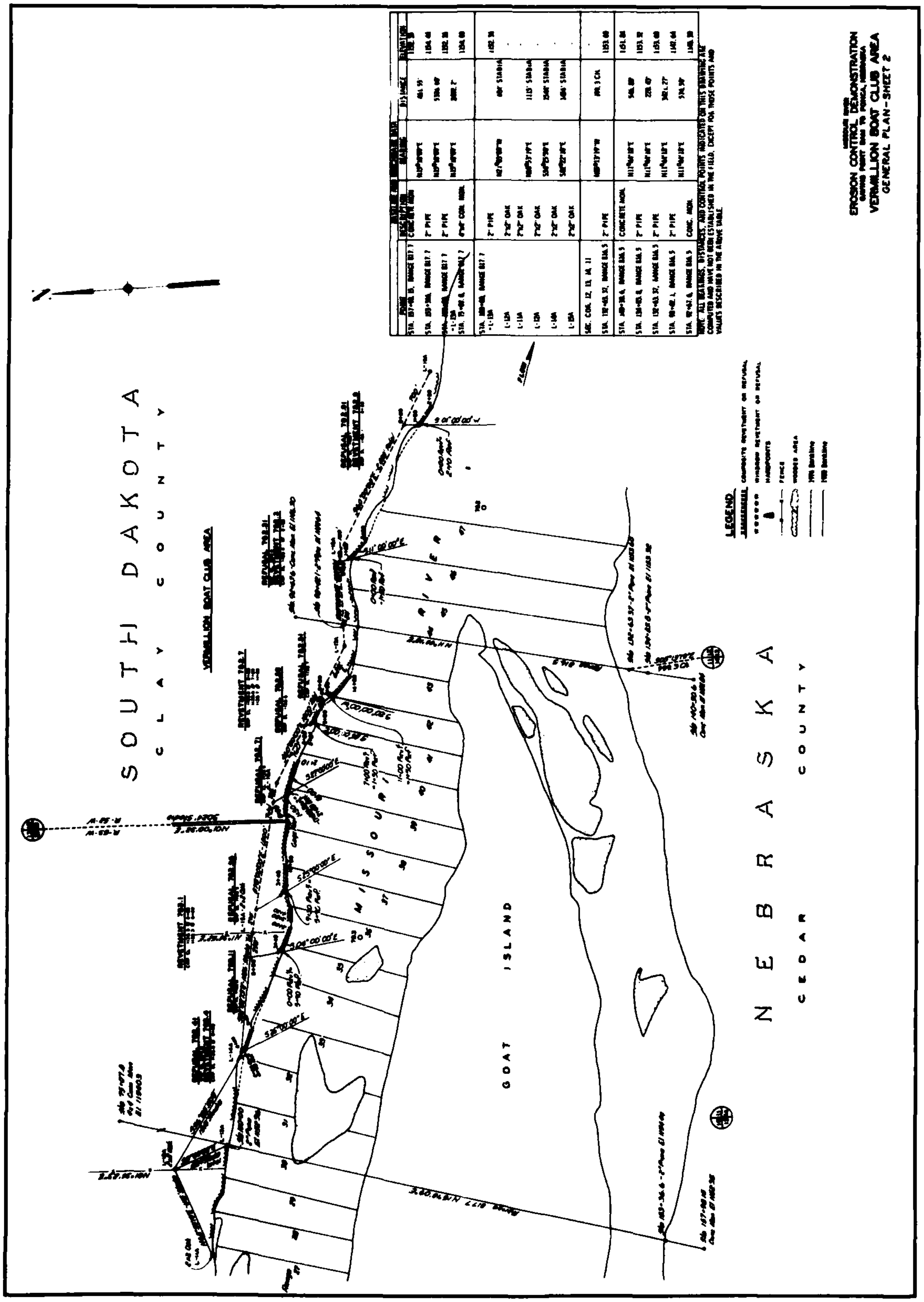

SOUTH DAKOTA
CLAY COUNTY
VERMILLION BOAT CLUB AREA
NEBRASKA
CEDAR COUNTY
GOAT ISLAND
MISSOURI RIVER
LEGEND
EROSION CONTROL DEMONSTRATION
VERMILLION BOAT CLUB AREA
GENERAL PLAN-SHEET 2

PLATE 4-2

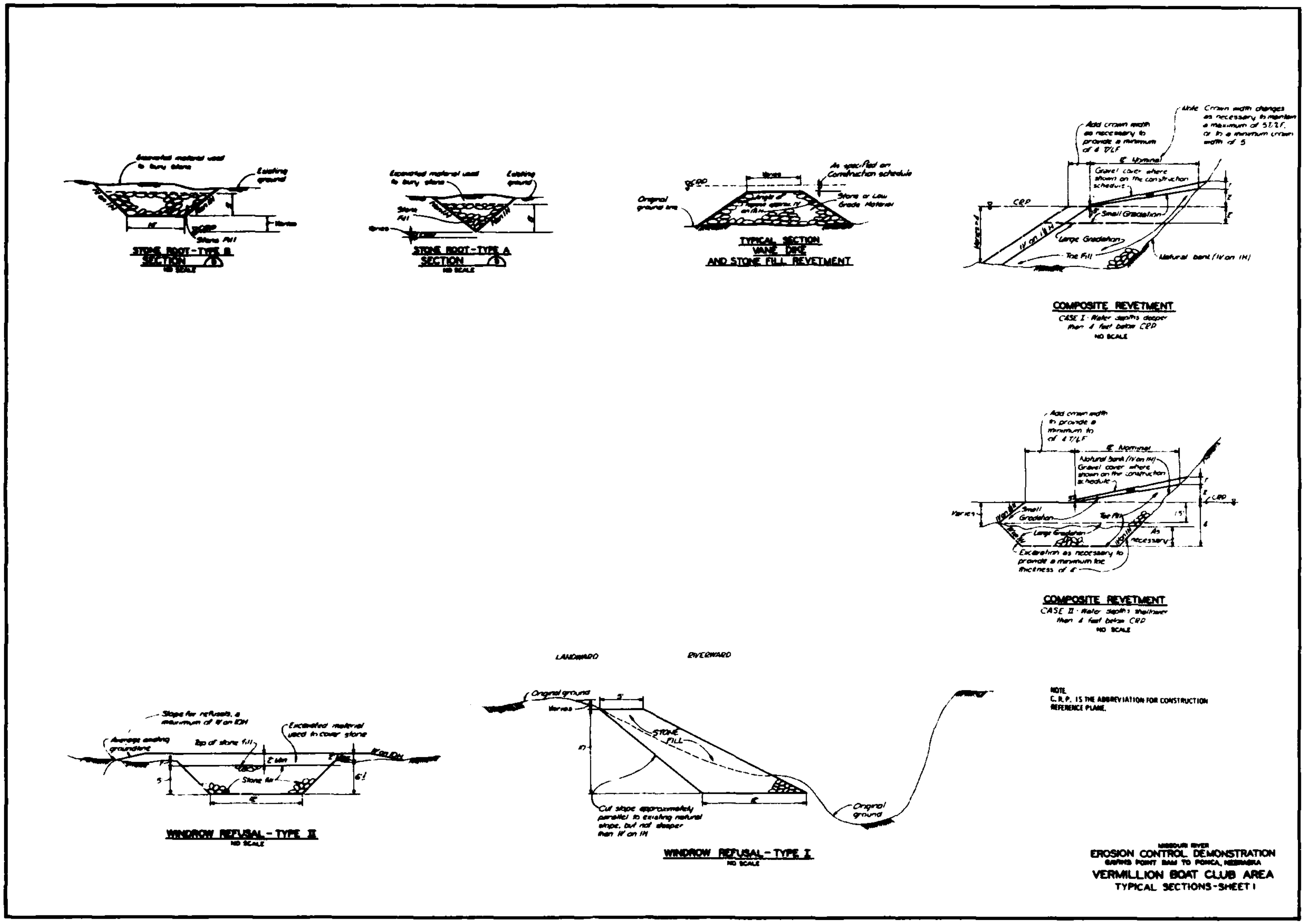

STONE BOOT - TYPE B
SECTION
NO SCALE
STONE BOOT - TYPE A
SECTION
NO SCALE
TYPICAL SECTION
VANE DIKE
AND STONE FILL REVETMENT
COMPOSITE REVETMENT
CASE I - Water depths deeper than 4 feet below CRP
NO SCALE
COMPOSITE REVETMENT
CASE II - Water depths shallower than 4 feet below CRP
NO SCALE
LANDWARD
RIVERWARD
STONE FILL
WINDROW REFUSAL - TYPE II
NO SCALE
WINDROW REFUSAL - TYPE I
NO SCALE
NOTE.
C.R.P. IS THE ABBREVIATION FOR CONSTRUCTION REFERENCE PLANE.
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
VERMILLION BOAT CLUB AREA
TYPICAL SECTIONS-SHEET 1

PLATE 4-3

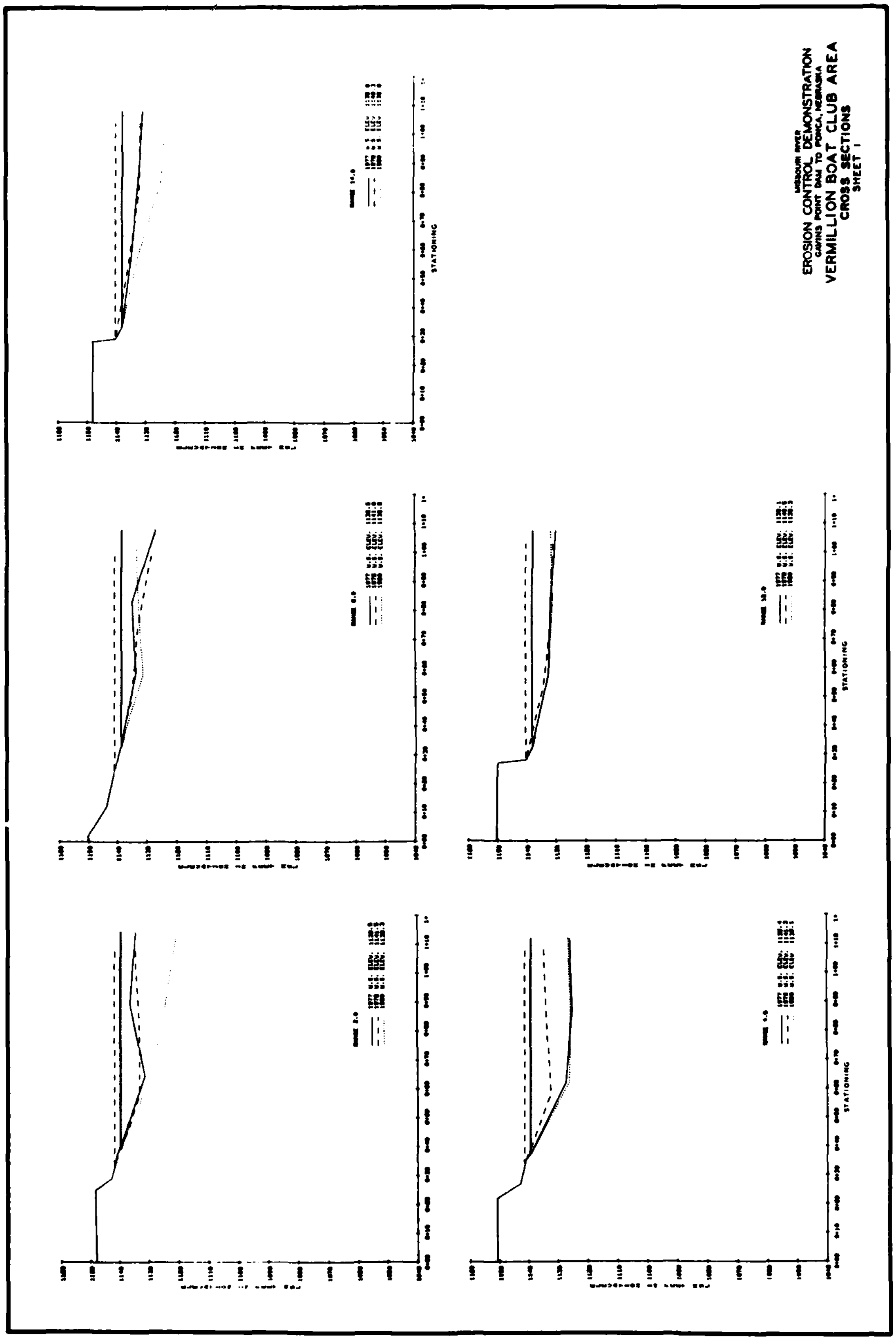

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
VERMILLION BOAT CLUB AREA
CROSS SECTIONS
SHEET 1
STATIONING

PLATE 4-4

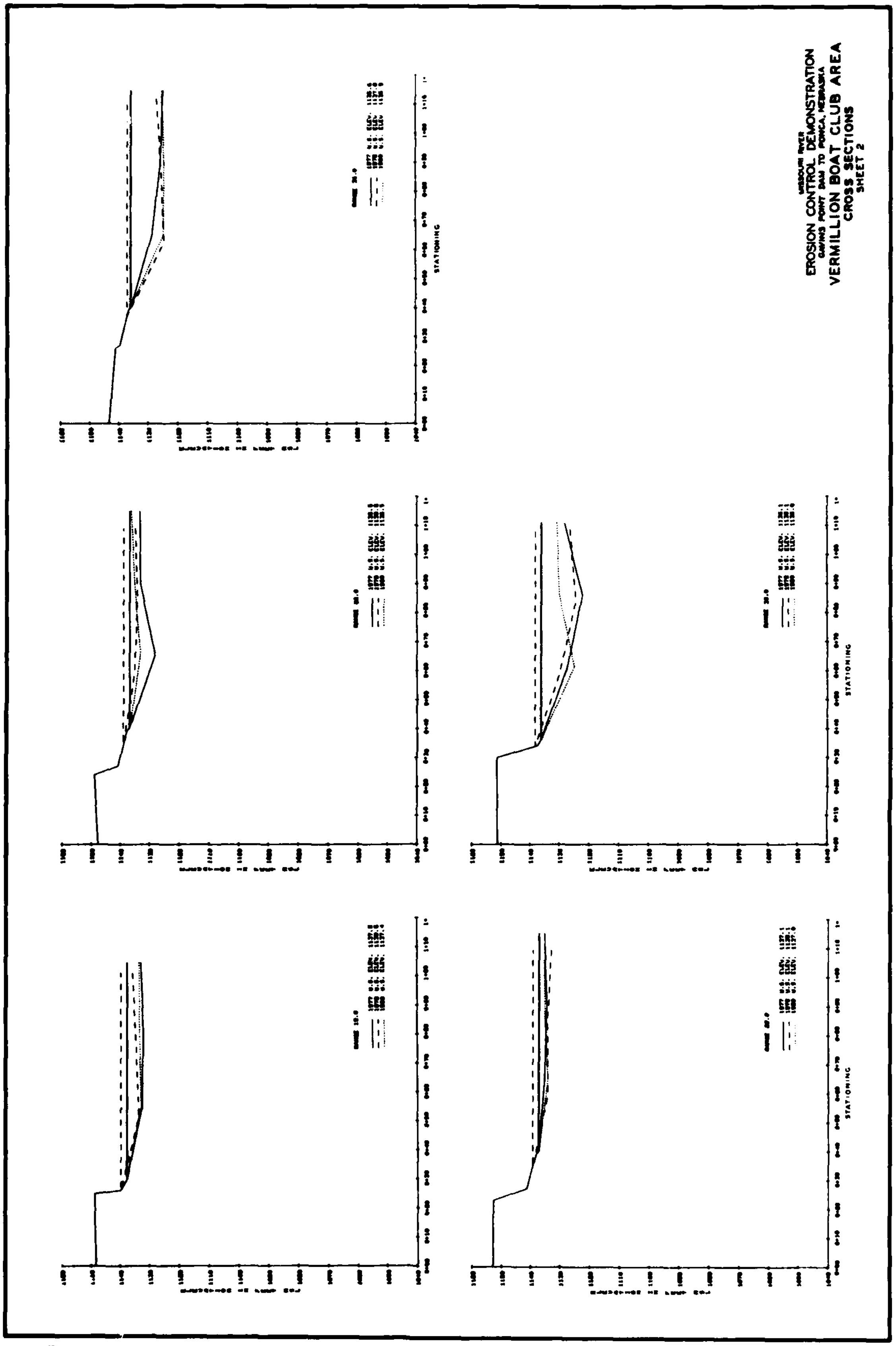
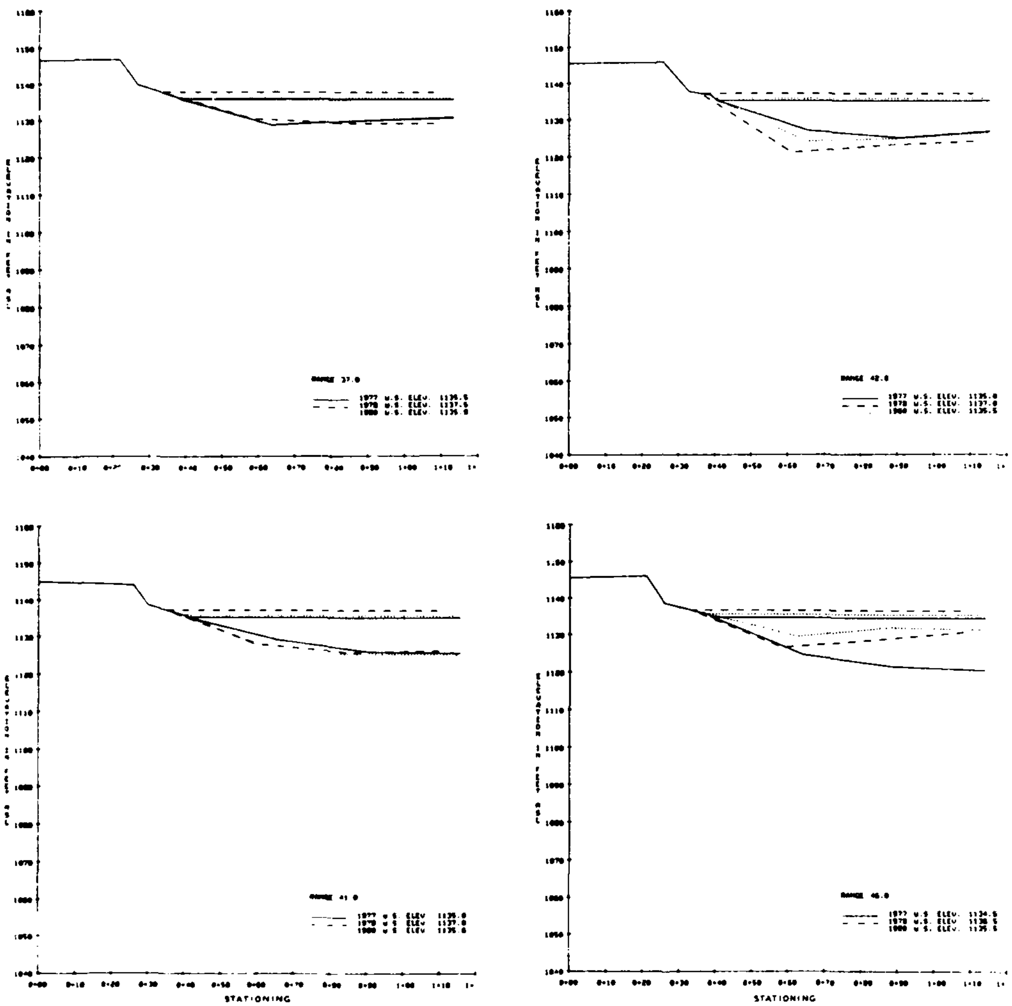

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
VERMILLION BOAT CLUB AREA
CROSS SECTIONS
SHEET 2
STATIONING

PLATE 4-5



MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
VERMILLION BOAT CLUB AREA
CROSS SECTIONS
SHEET 3

PLATE 4-6

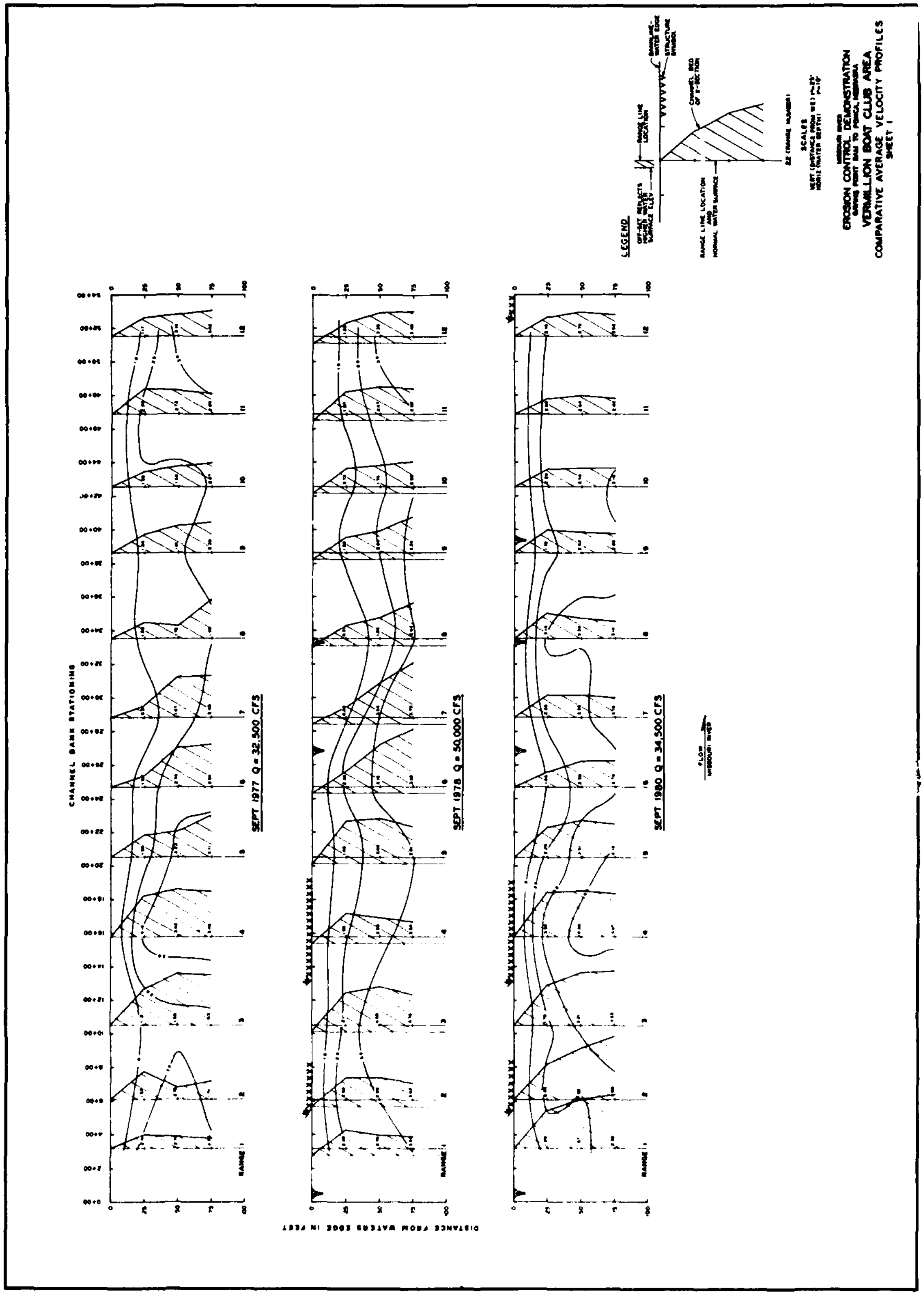

CHANNEL BANK STATIONING
DISTANCE FROM WATERS EDGE IN FEET
SEPT 1977 Q = 32,500 CFS
SEPT 1978 Q = 50,000 CFS
SEPT 1980 Q = 34,500 CFS
FLOW
MISSOURI RIVER
LEGEND
RANGE LINE LOCATION
RANGE LINE LOCATION AND NORMAL WATER SURFACE
CHANNEL BED OF X-SECTION
22 (RANGE NUMBER)
SCALES
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
VERMILLION BOAT CLUB AREA
COMPARATIVE AVERAGE VELOCITY PROFILES
SHEET 1

PLATE 4-7

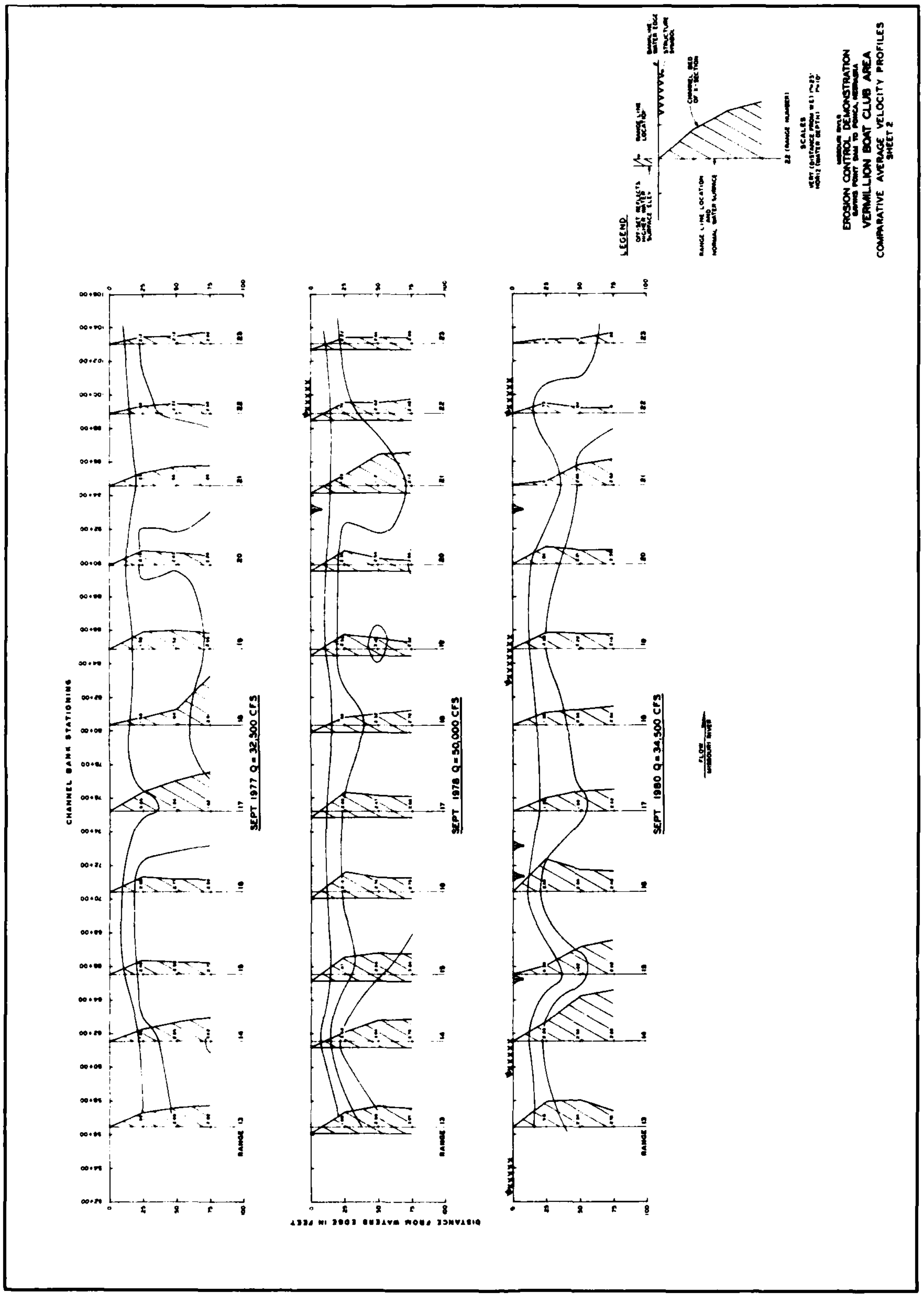

LEGEND
EROSION CONTROL DEMONSTRATION
VERMILLION BOAT CLUB AREA
COMPARATIVE AVERAGE VELOCITY PROFILES
SHEET 2
CHANNEL BANK STATIONING
SEPT 1977 Q = 32,500 CFS
SEPT 1978 Q = 50,000 CFS
SEPT 1980 Q = 34,500 CFS
DISTANCE FROM WATERS EDGE IN FEET

PLATE 4-8

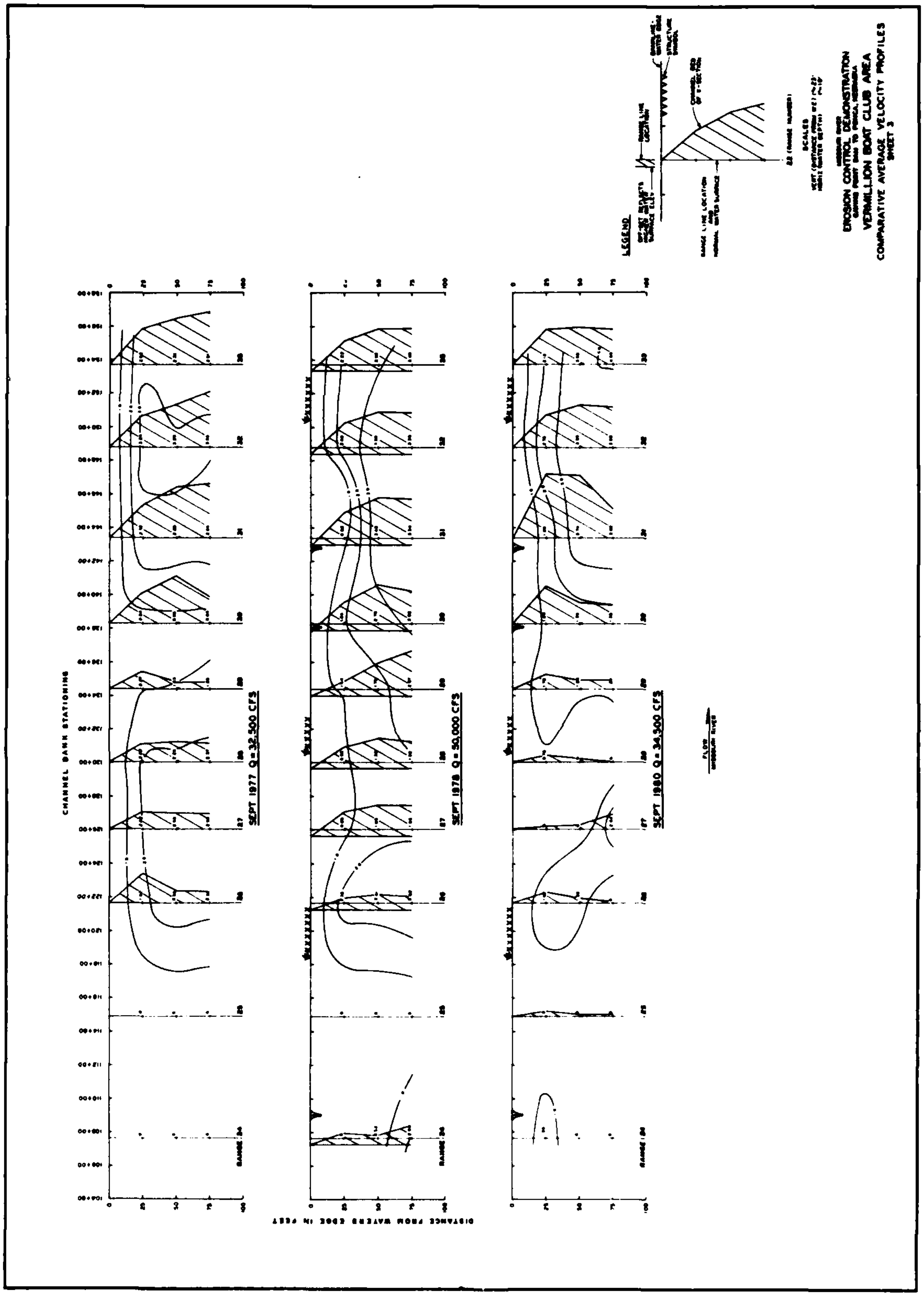

LEGEND
EROSION CONTROL DEMONSTRATION
VERMILLION BOAT CLUB AREA
COMPARATIVE AVERAGE VELOCITY PROFILES
SEPT 1977 Q=32,500 CFS
SEPT 1978 Q=30,000 CFS
SEPT 1980 Q=34,500 CFS
CHANNEL BANK STATIONING
DISTANCE FROM WATERS EDGE IN FEET

PLATE 4-9

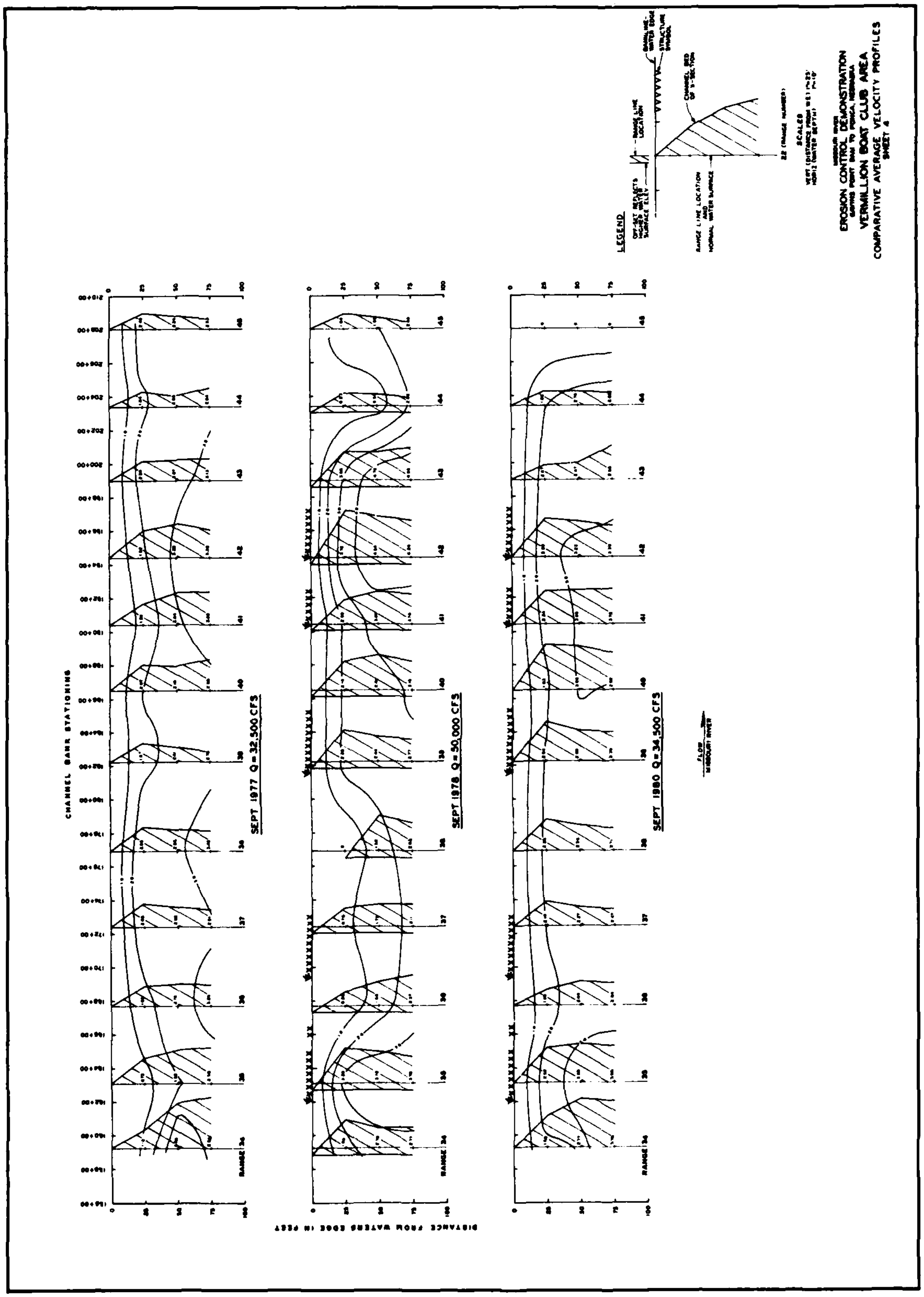

LEGEND
RANGE LINE LOCATION
CHANNEL BED OF X-SECTION
RANGE LINE LOCATION AND NORMAL WATER SURFACE
SCALES
EROSION CONTROL DEMONSTRATION
VERMILLION BOAT CLUB AREA
COMPARATIVE AVERAGE VELOCITY PROFILES
SHEET 4
CHANNEL BANK STATIONING
SEPT 1977 Q=32,500 CFS
SEPT 1978 Q=50,000 CFS
SEPT 1980 Q=34,500 CFS
DISTANCE FROM WATERS EDGE IN FEET
FLOW
MISSOURI RIVER

PLATE 4-10

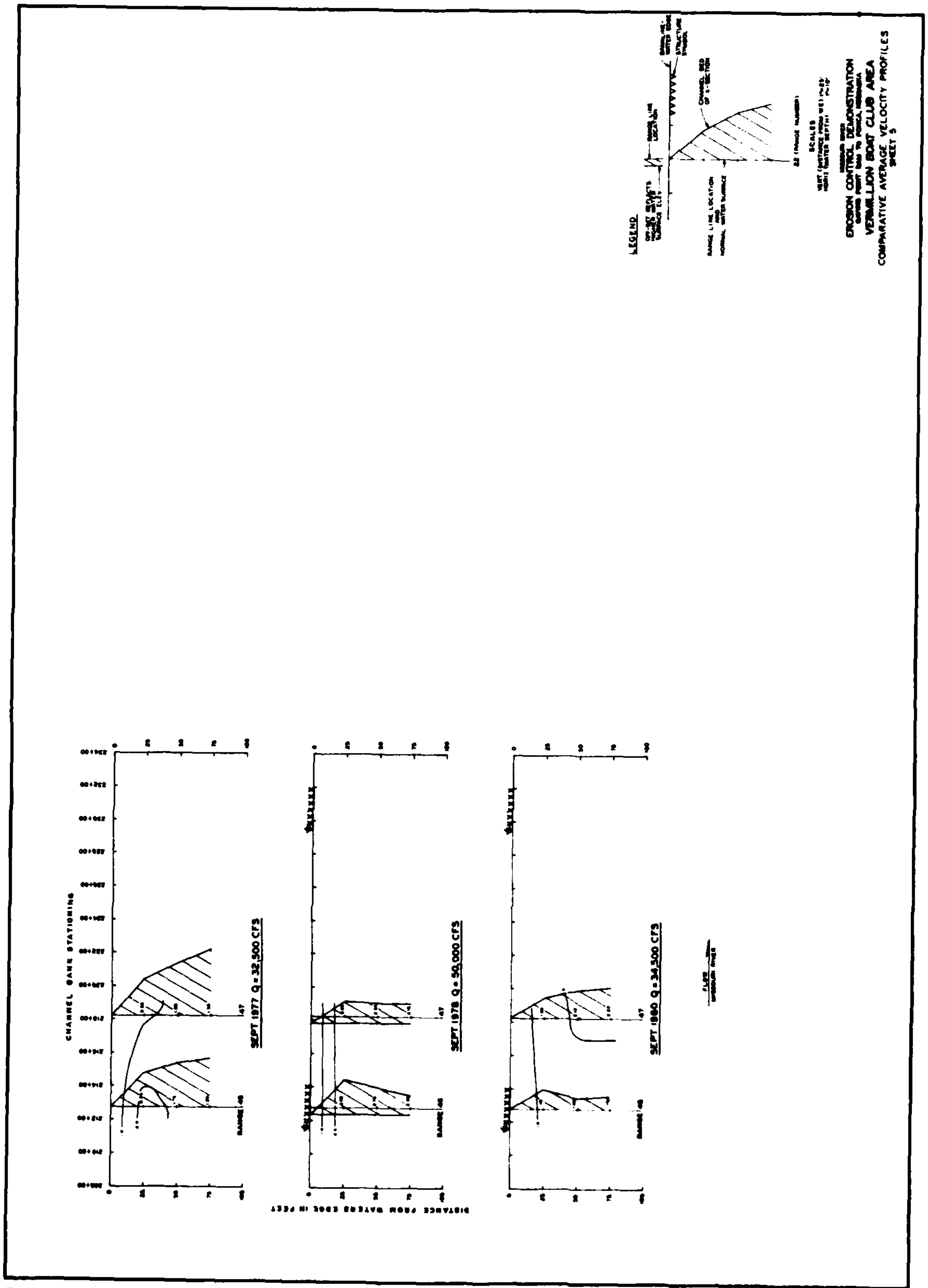

LEGEND
CHANNEL BANK STATIONING
SEPT 1977 Q = 32,500 CFS
SEPT 1978 Q = 50,000 CFS
SEPT 1980 Q = 34,500 CFS
DISTANCE FROM WATERS EDGE IN FEET
EROSION CONTROL DEMONSTRATION
VERMILLION BOAT CLUB AREA
COMPARATIVE AVERAGE VELOCITY PROFILES
SHEET 5

PLATE 4-11

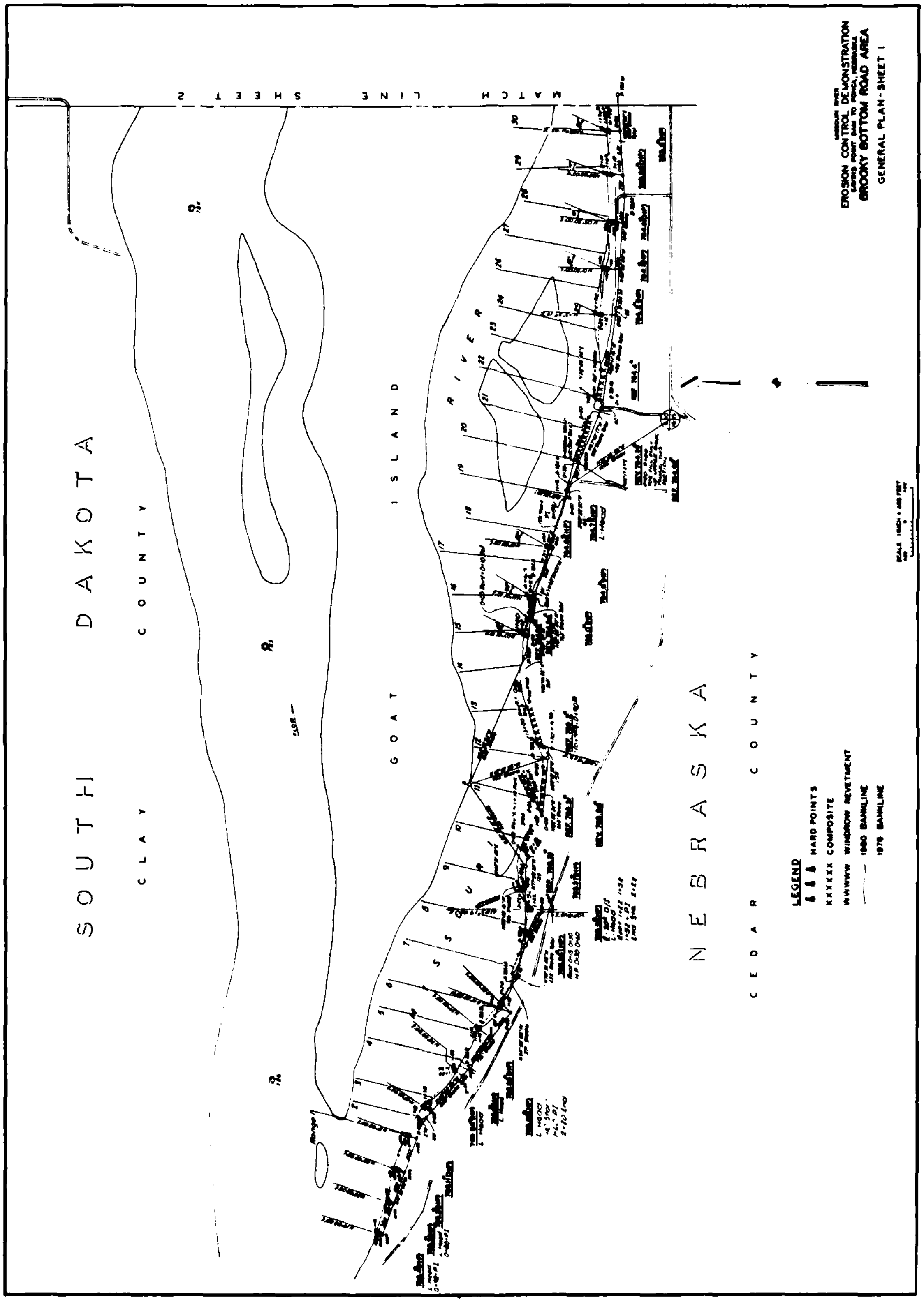

EROSION CONTROL DEMONSTRATION
BROOKY BOTTOM ROAD AREA
GENERAL PLAN-SHEET 1
MATCH LINE SHEET 2
SOUTH DAKOTA
CLAY COUNTY
GOAT ISLAND
MISSOURI RIVER
NEBRASKA
CEDAR COUNTY
LEGEND
HARD POINTS
XXXXXX COMPOSITE
WWWWW WINDROW REVETMENT
1980 BANKLINE
1979 BANKLINE

PLATE 5-1

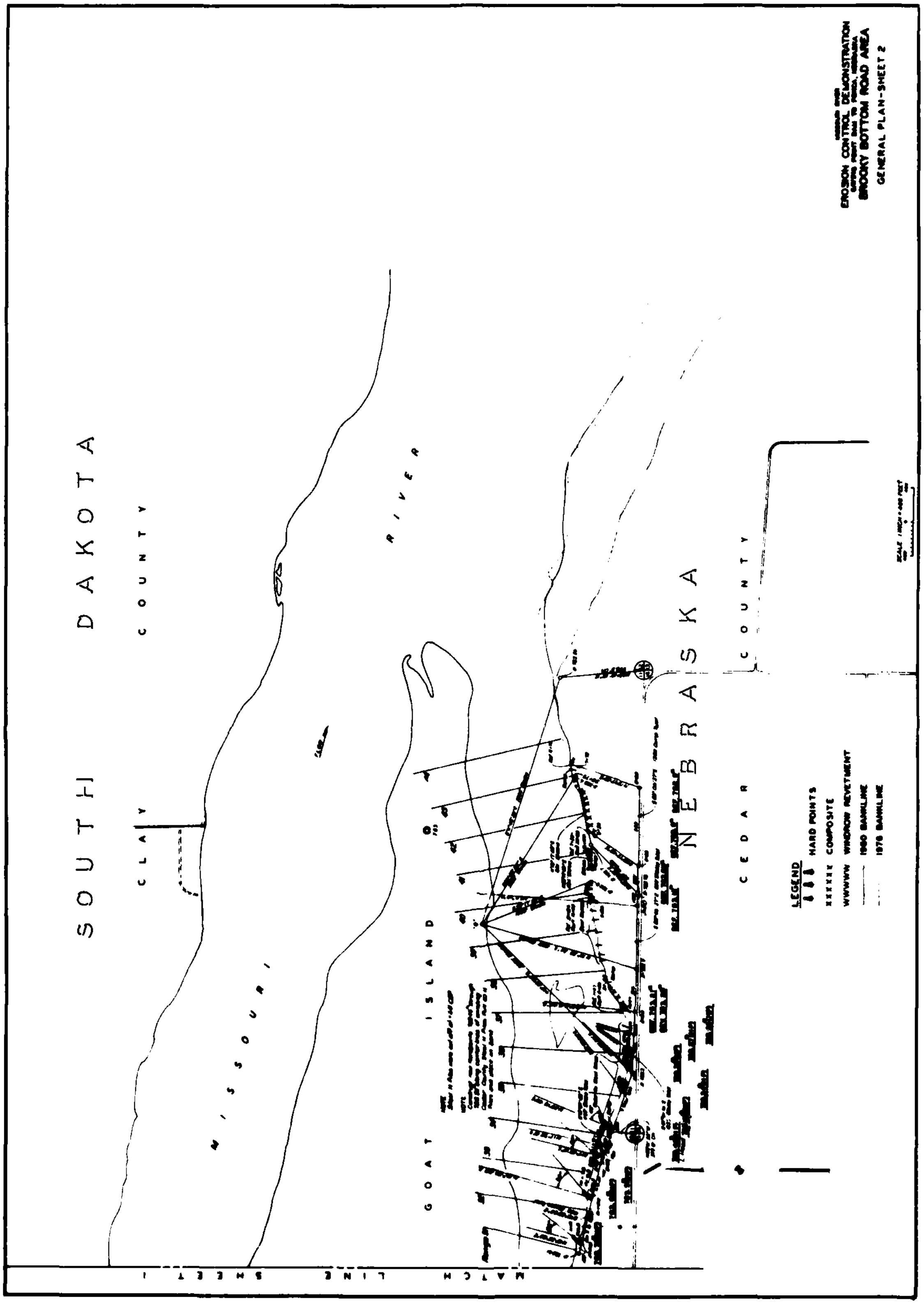

EROSION CONTROL DEMONSTRATION
BROOKY BOTTOM ROAD AREA
GENERAL PLAN-SHEET 2
SOUTH DAKOTA
CLAY COUNTY
MISSOURI RIVER
GOAT ISLAND
NEBRASKA
CEDAR COUNTY
LEGEND
HARD POINTS
COMPOSITE
WINDROW REVETMENT
1960 BANKLINE
1976 BANKLINE
MATCH LINE SHEET 1

PLATE 5-2

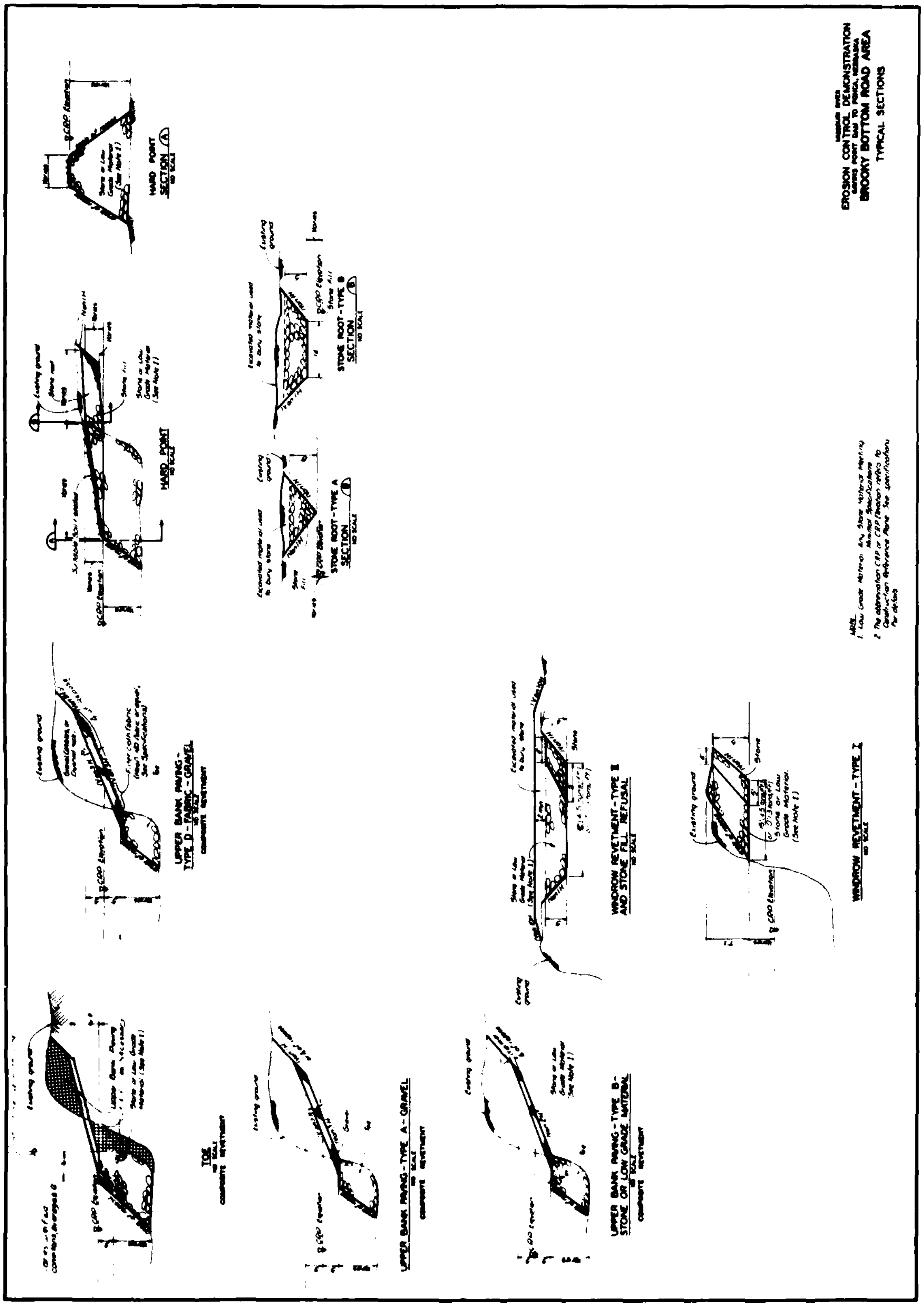

EROSION CONTROL DEMONSTRATION
BROOKY BOTTOM ROAD AREA
TYPICAL SECTIONS
HARD POINT
SECTION A
STONE ROOT-TYPE A
SECTION B
STONE ROOT-TYPE B
SECTION B
UPPER BANK PAVING-TYPE D-FABRIC-GRAVEL
WINDROW REVETMENT-TYPE II AND STONE FILL REFUSAL
WINDROW REVETMENT-TYPE I
TOE
UPPER BANK PAVING-TYPE A-GRAVEL
UPPER BANK PAVING-TYPE B-STONE OR LOW GRADE MATERIAL

PLATE 5-3

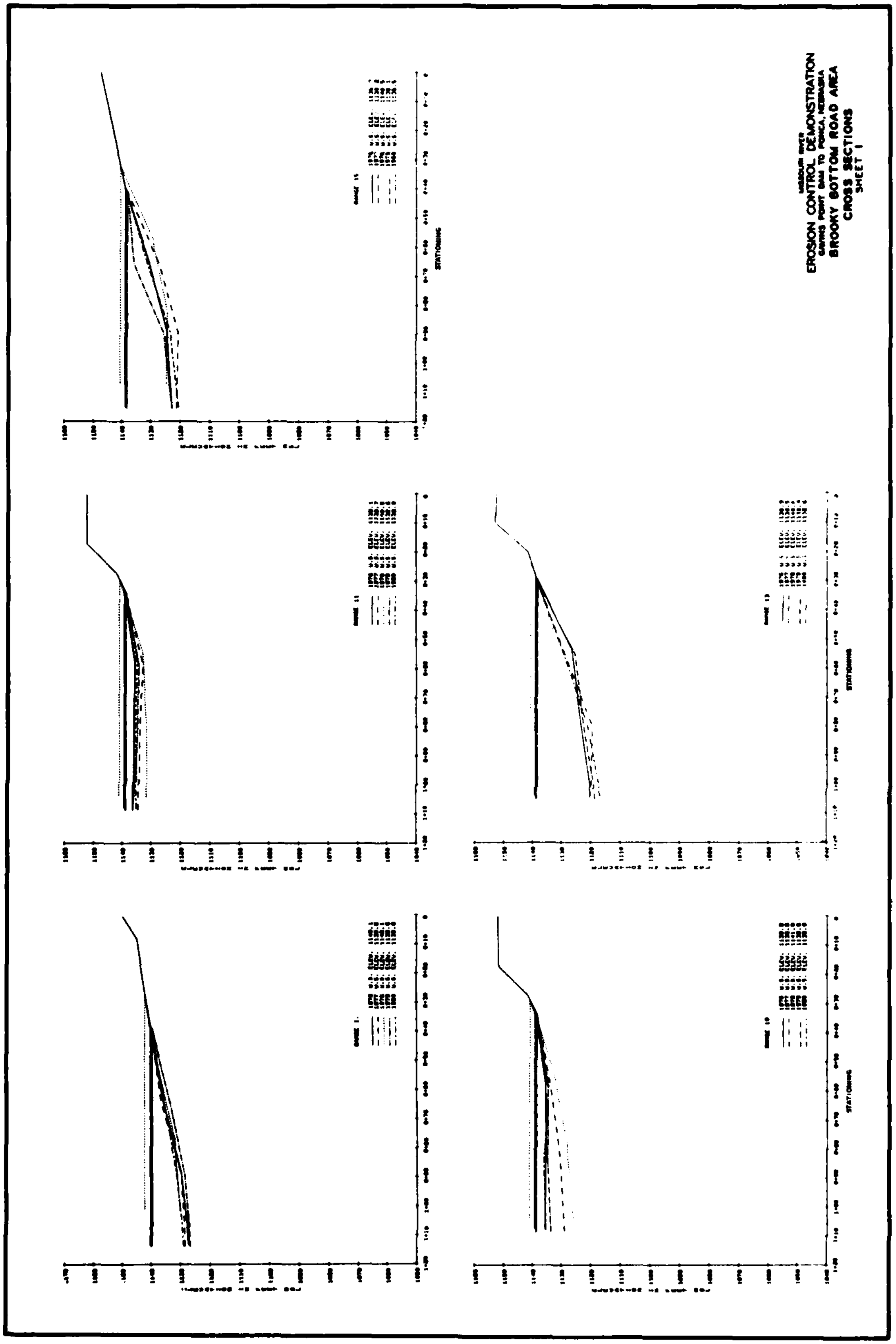

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
BROOKY BOTTOM ROAD AREA
CROSS SECTIONS
SHEET 1
STATIONING

PLATE 5-4

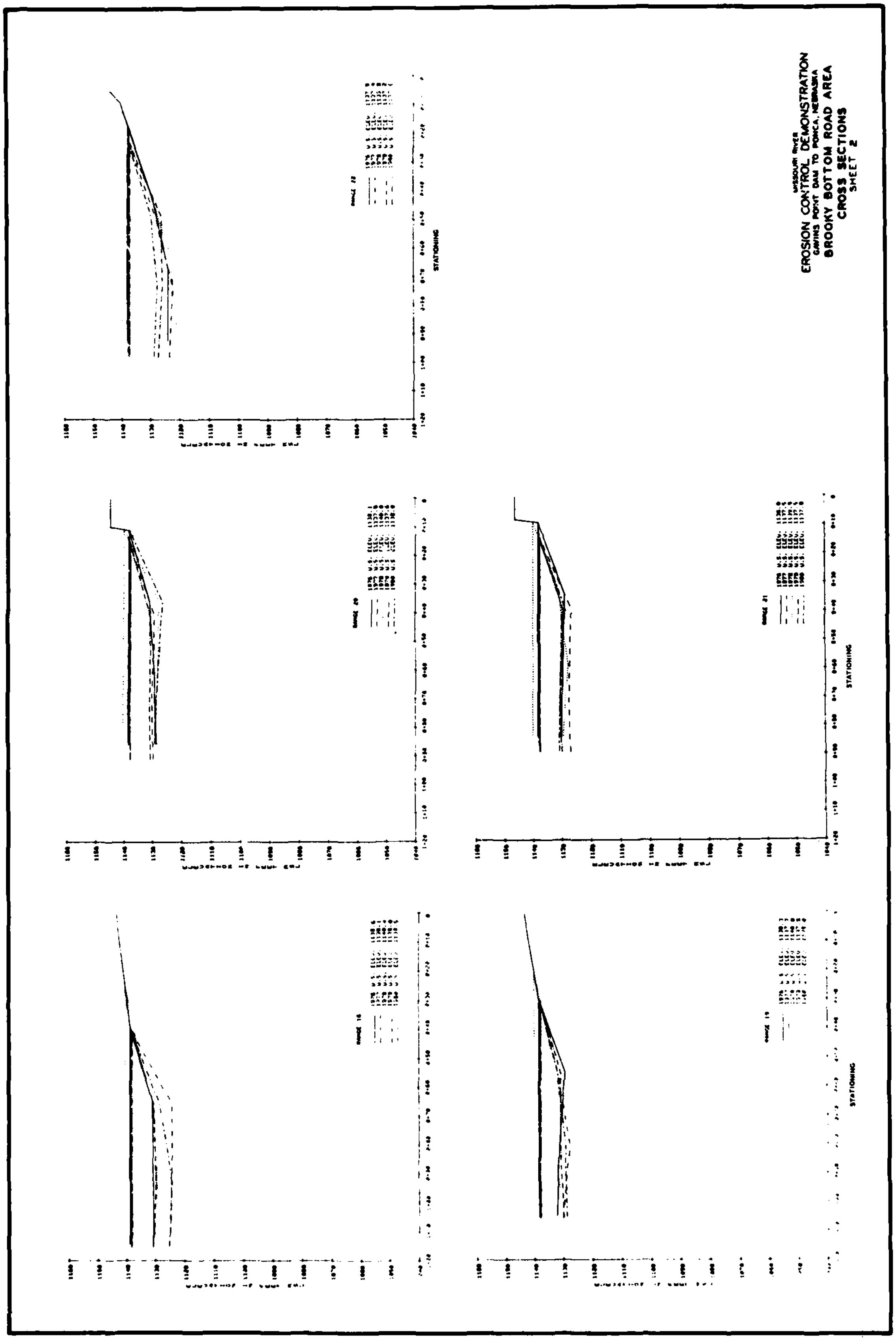

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
BROOKY BOTTOM ROAD AREA
CROSS SECTIONS
SHEET 2
STATIONING

PLATE 5-5

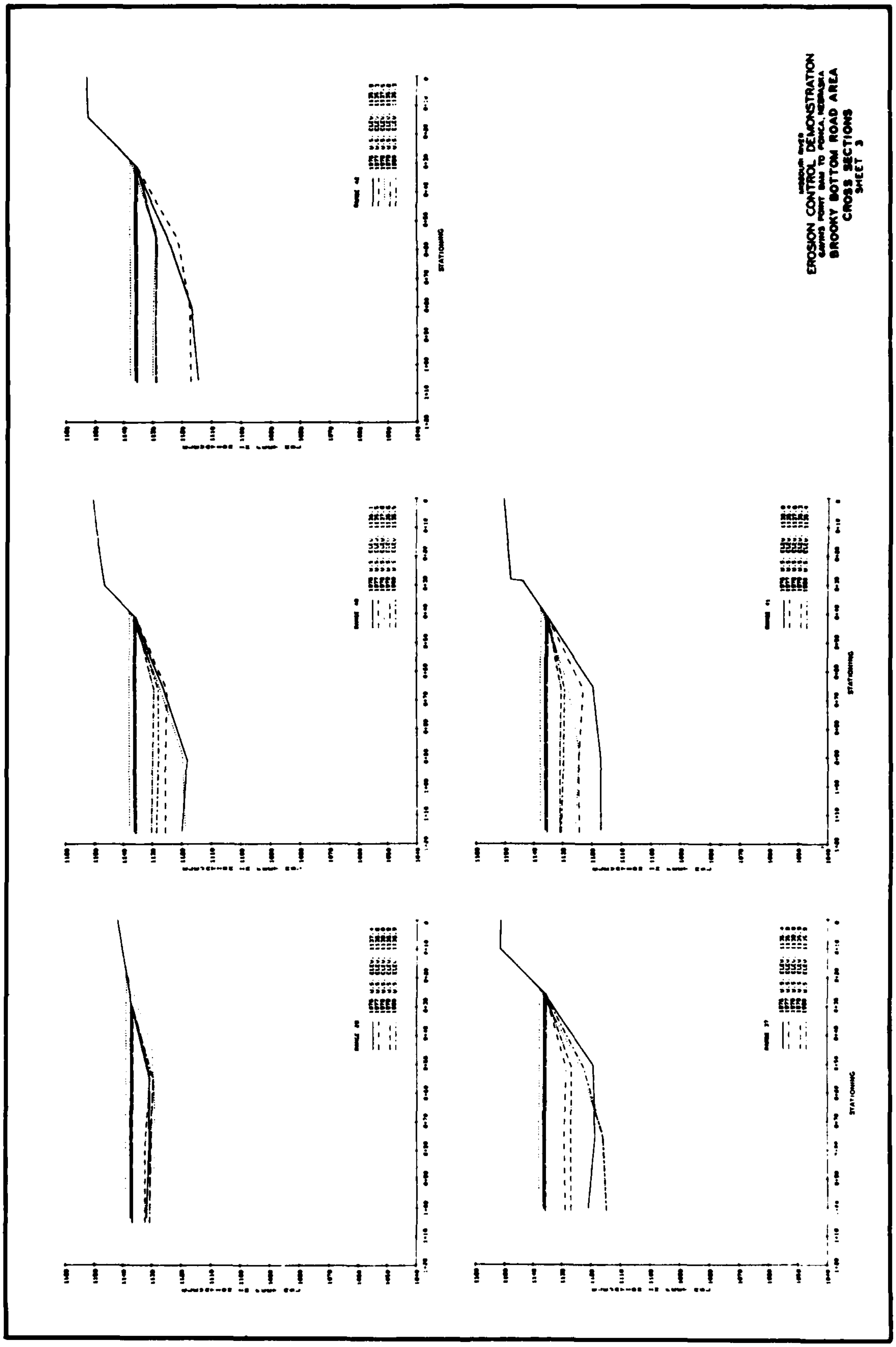
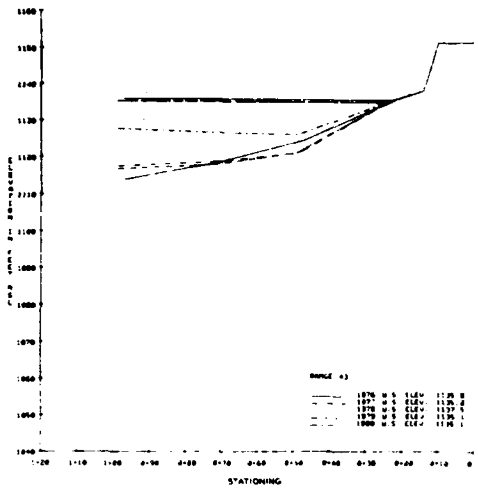

EROSION CONTROL DEMONSTRATION
BROOKY BOTTOM ROAD AREA
CROSS SECTIONS
SHEET 3
STATIONING

PLATE 5-6



MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
BROOKY BOTTOM ROAD AREA
CROSS SECTIONS
SHEET 4

PLATE 5-7

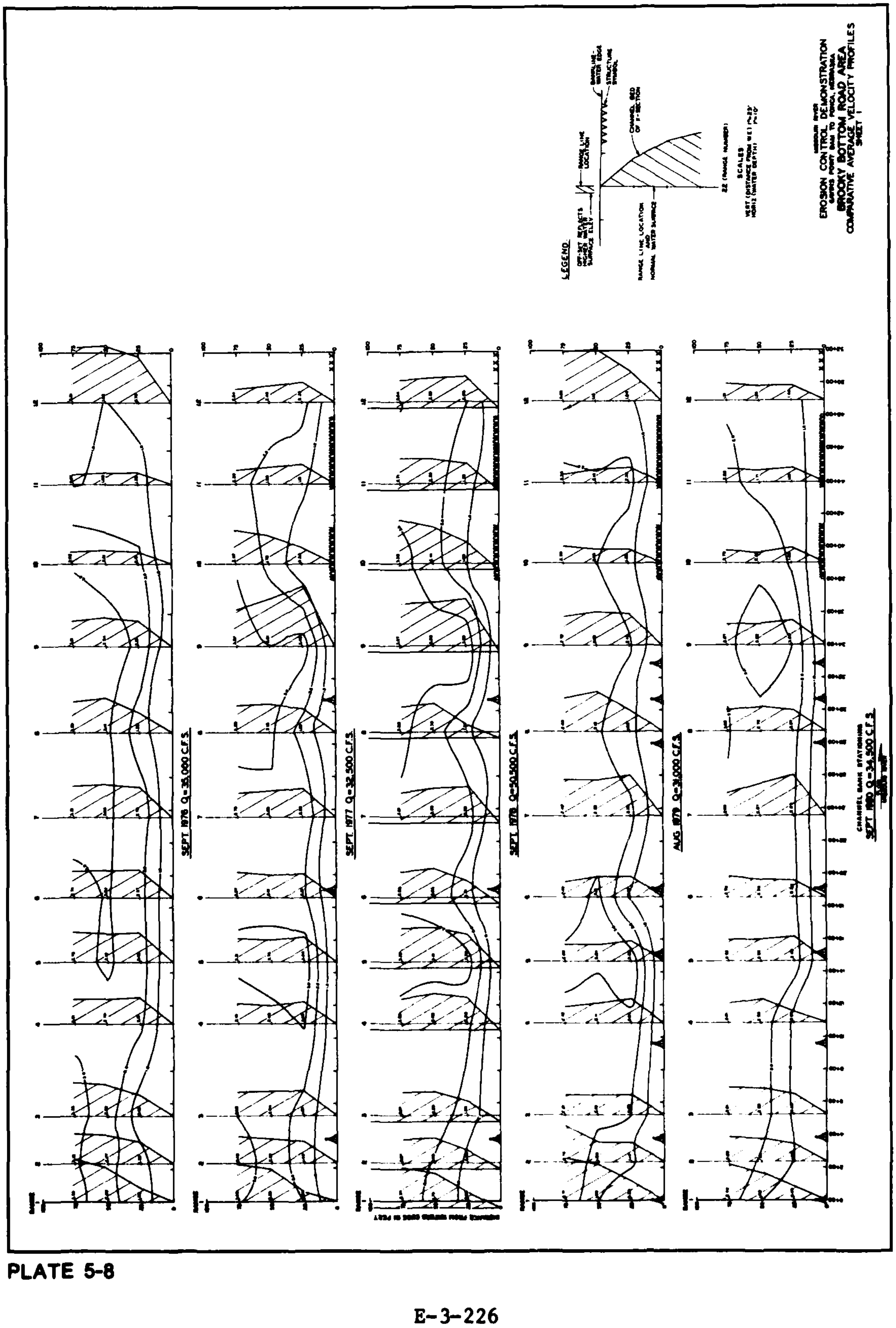
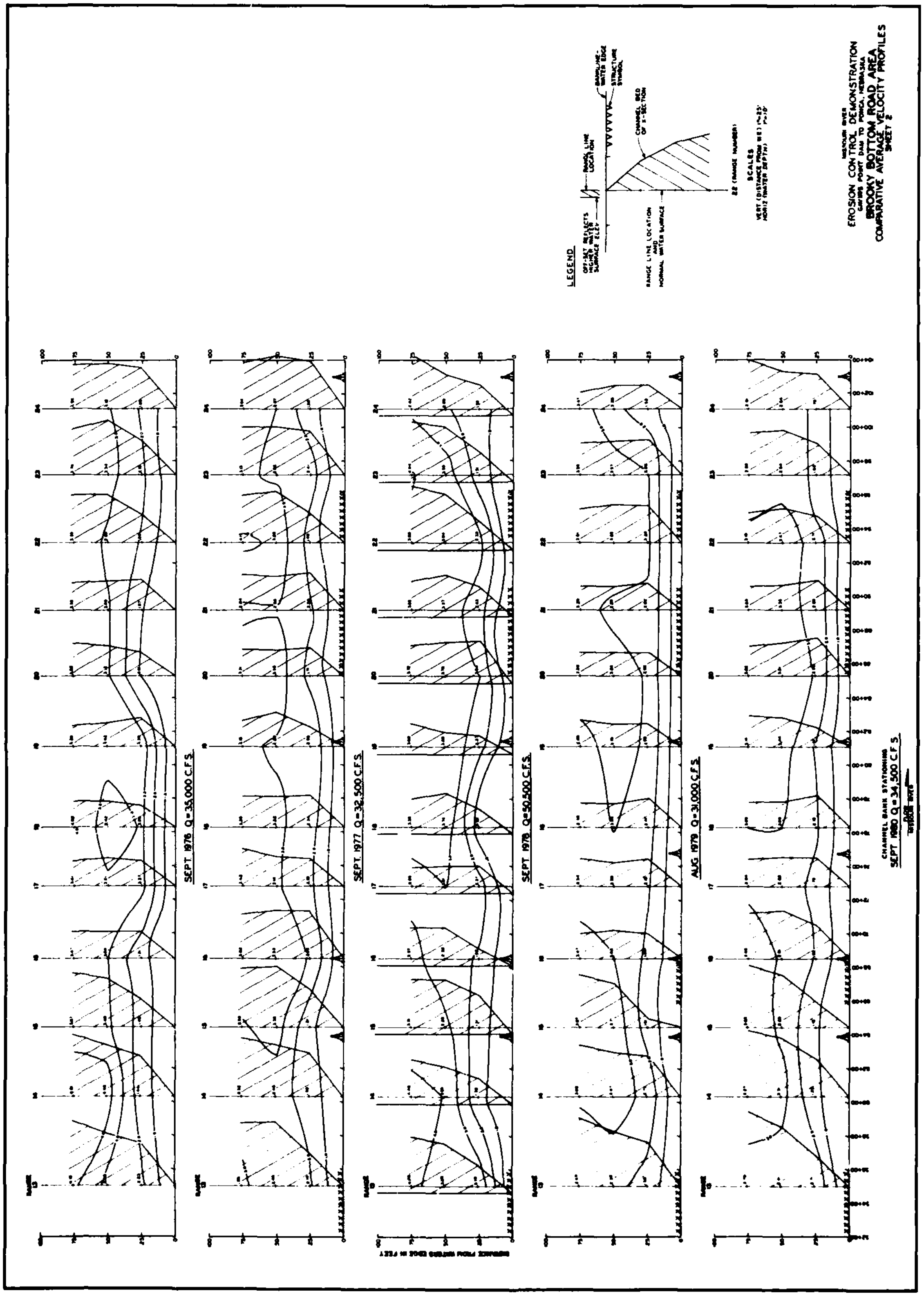
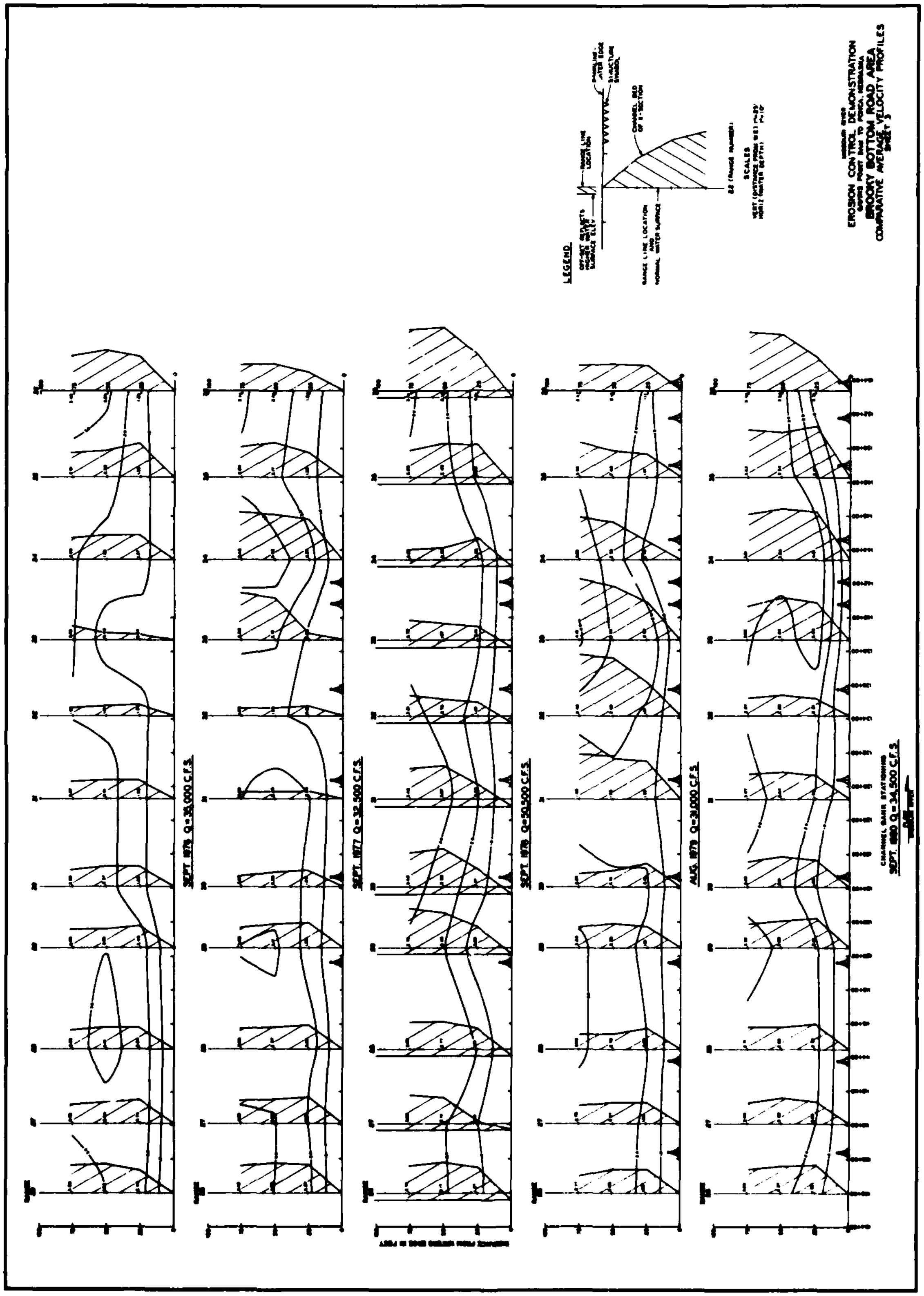

EROSION CONTROL DEMONSTRATION
BROOKY BOTTOM ROAD AREA
COMPARATIVE AVERAGE VELOCITY PROFILES
SHEET 1
LEGEND
SEPT 1976 Q=35,000 C.F.S.
SEPT 1977 Q=32,500 C.F.S.
SEPT 1978 Q=50,500 C.F.S.
AUG 1979 Q=31,000 C.F.S.
SEPT 1980 Q=34,500 C.F.S.

PLATE 5-8



MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
BROOKY BOTTOM ROAD AREA
COMPARATIVE AVERAGE VELOCITY PROFILES
SHEET 2
LEGEND
SCALES
SEPT 1976 Q=35,000 C.F.S.
SEPT 1977 Q=32,500 C.F.S.
SEPT 1978 Q=50,500 C.F.S.
AUG 1979 Q=31,000 C.F.S.
SEPT 1980 Q=34,500 C.F.S.
CHANNEL BANK STATIONING

PLATE 5-9



EROSION CONTROL DEMONSTRATION
BROOKY BOTTOM ROAD AREA
COMPARATIVE AVERAGE VELOCITY PROFILES
LEGEND
SEPT. 1976 Q=35,000 C.F.S.
SEPT. 1977 Q=32,500 C.F.S.
SEPT. 1978 Q=50,500 C.F.S.
AUG. 1979 Q=31,000 C.F.S.
SEPT. 1980 Q=34,500 C.F.S.

PLATE 5-10

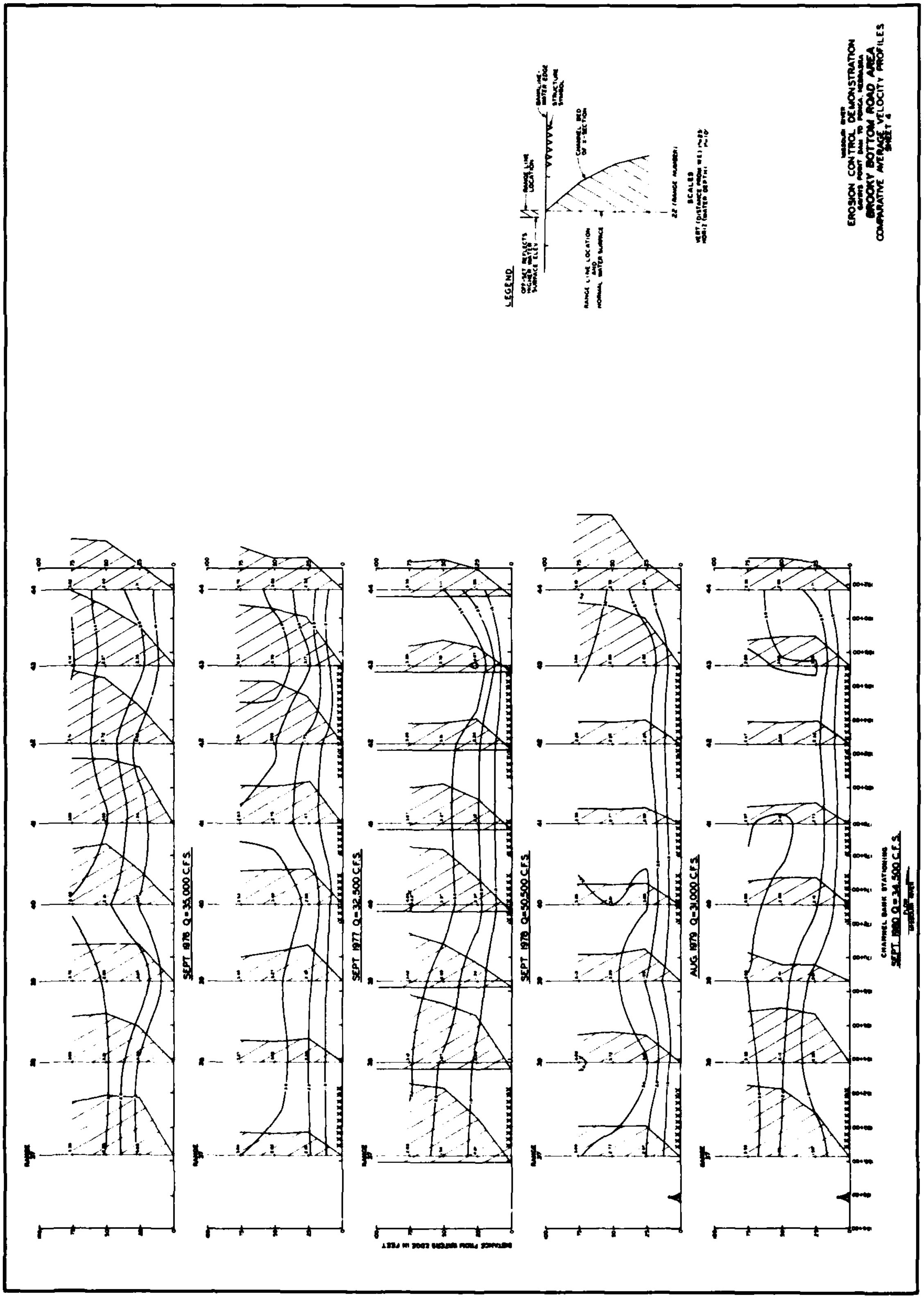

SEPT 1976 Q=35,000 C.F.S.
SEPT 1977 Q=32,500 C.F.S.
SEPT 1978 Q=50,500 C.F.S.
AUG 1979 Q=31,000 C.F.S.
CHANNEL BANK STATIONING
SEPT 1980 Q=34,500 C.F.S.
LEGEND
SCALES
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
BROOKY BOTTOM ROAD AREA
COMPARATIVE AVERAGE VELOCITY PROFILES
SHEET 4

PLATE 5-11

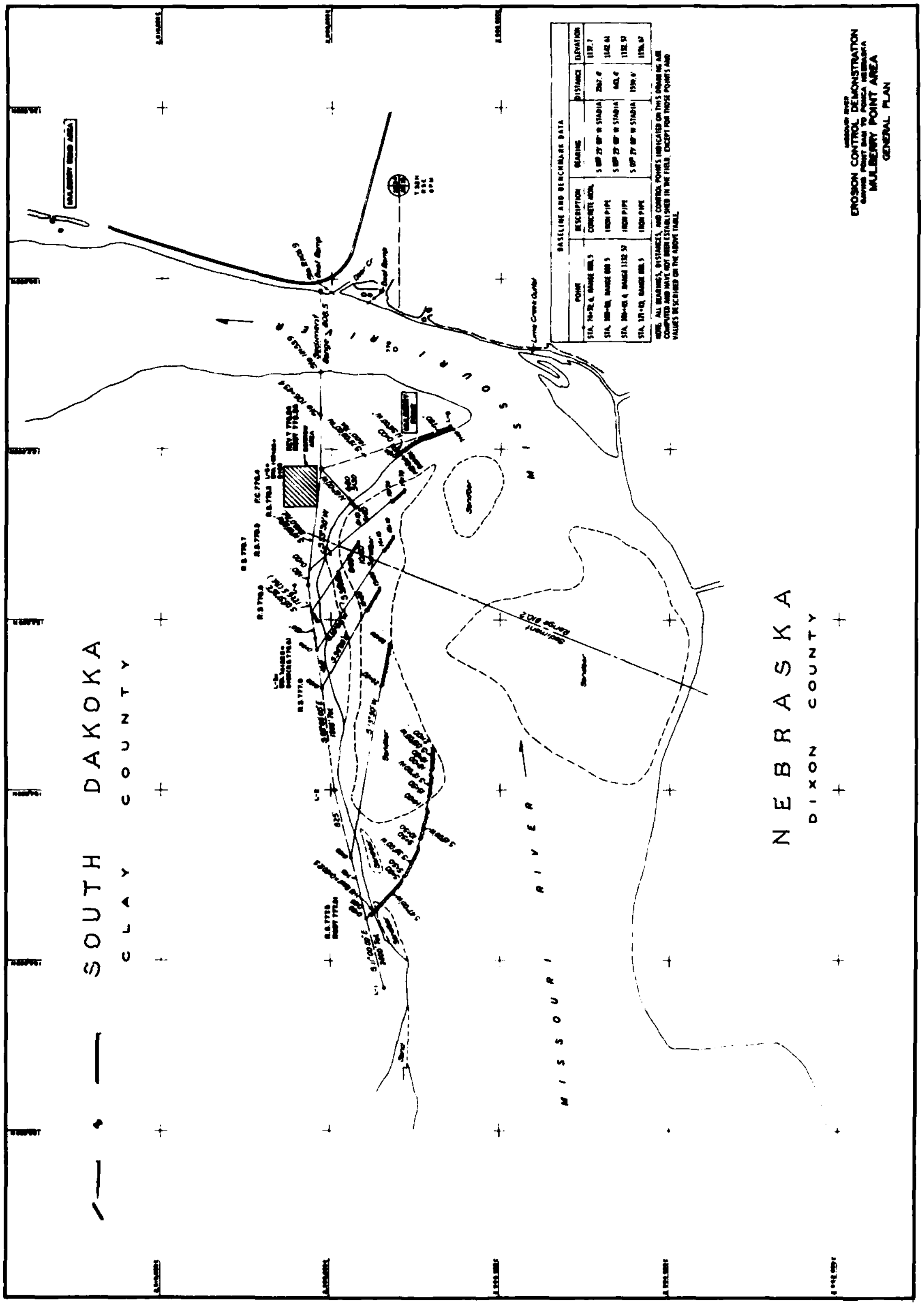

SOUTH DAKOKA
CLAY COUNTY
NEBRASKA
DIXON COUNTY
MISSOURI RIVER
MISSOURI
EROSION CONTROL DEMONSTRATION
MULBERRY POINT AREA
GENERAL PLAN

PLATE 6-1

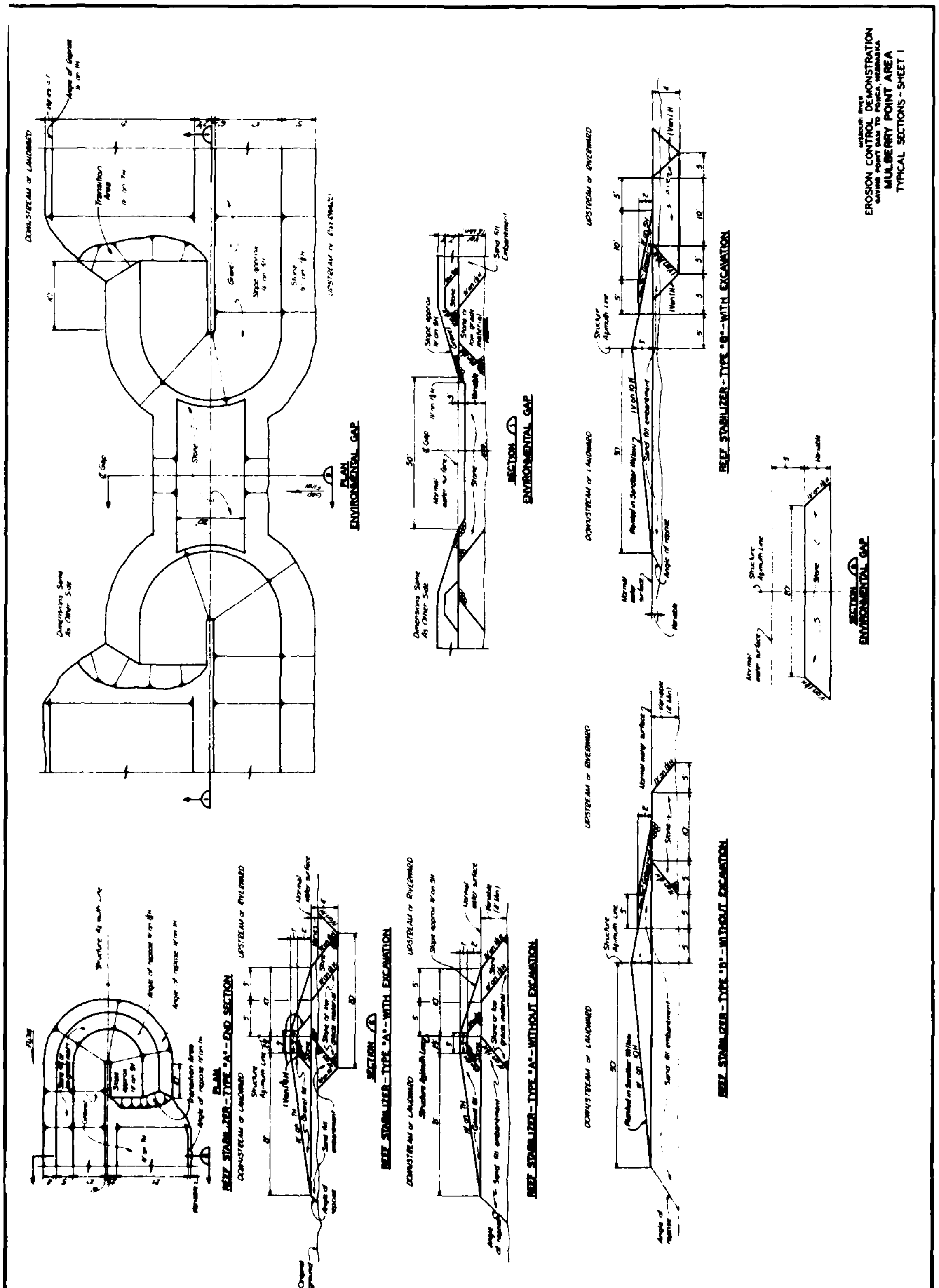

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
MULBERRY POINT AREA
TYPICAL SECTIONS - SHEET 1
PLAN
ENVIRONMENTAL GAP
SECTION A
ENVIRONMENTAL GAP
SECTION B
ENVIRONMENTAL GAP
REEF STABILIZER - TYPE "B" - WITH EXCAVATION
REEF STABILIZER - TYPE "B" - WITHOUT EXCAVATION
REEF STABILIZER - TYPE "A" - WITH EXCAVATION
REEF STABILIZER - TYPE "A" - WITHOUT EXCAVATION
PLAN
REEF STABILIZER - TYPE "A" - END SECTION
DOWNSTREAM or LANDWARD
UPSTREAM or RIVERWARD

PLATE 6-2

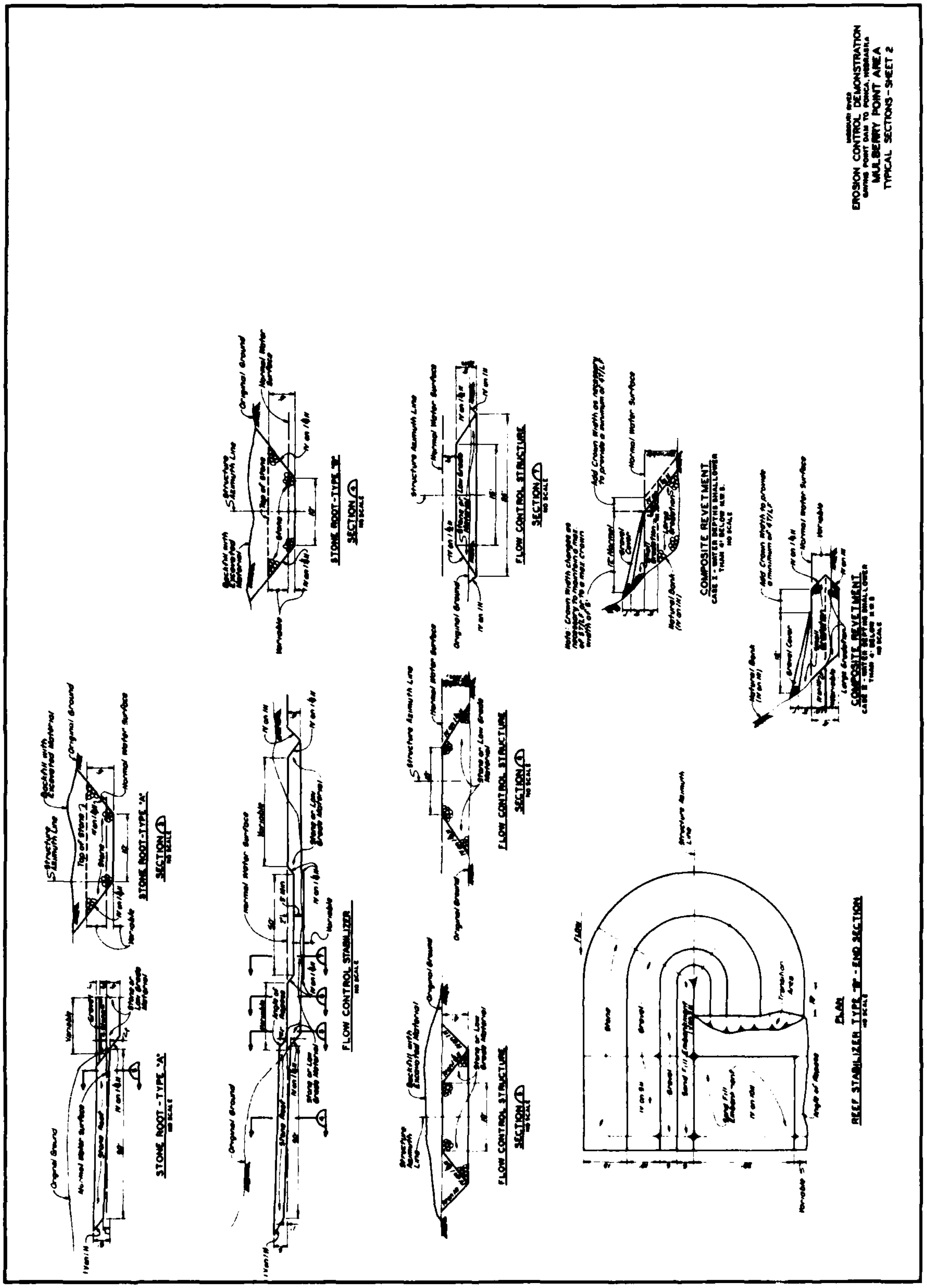

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
MULBERRY POINT AREA
TYPICAL SECTIONS - SHEET 2
STONE ROOT - TYPE "A"
STONE ROOT - TYPE "A"
SECTION
STONE ROOT - TYPE "B"
SECTION
FLOW CONTROL STABILIZER
FLOW CONTROL STRUCTURE
SECTION
FLOW CONTROL STRUCTURE
SECTION
FLOW CONTROL STRUCTURE
SECTION
COMPOSITE REVETMENT
COMPOSITE REVETMENT
PLAN
REEF STABILIZER TYPE "B" - END SECTION
NO SCALE

PLATE 6-3

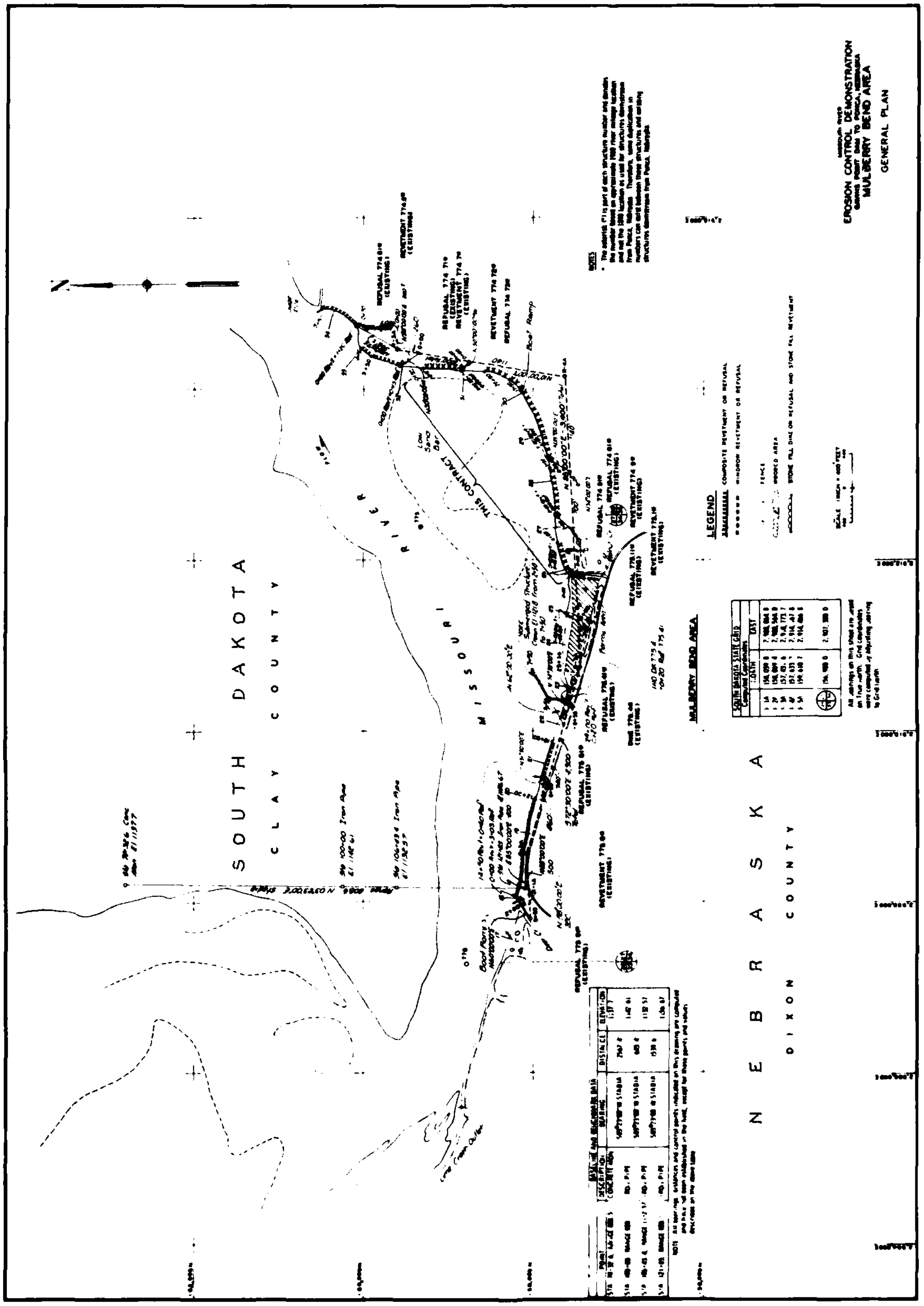

SOUTH DAKOTA
CLAY COUNTY
MISSOURI RIVER
THIS CONTRACT
NEBRASKA
DIXON COUNTY
LEGEND
MULBERRY BEND AREA
EROSION CONTROL DEMONSTRATION
MULBERRY BEND AREA
GENERAL PLAN

PLATE 7-1

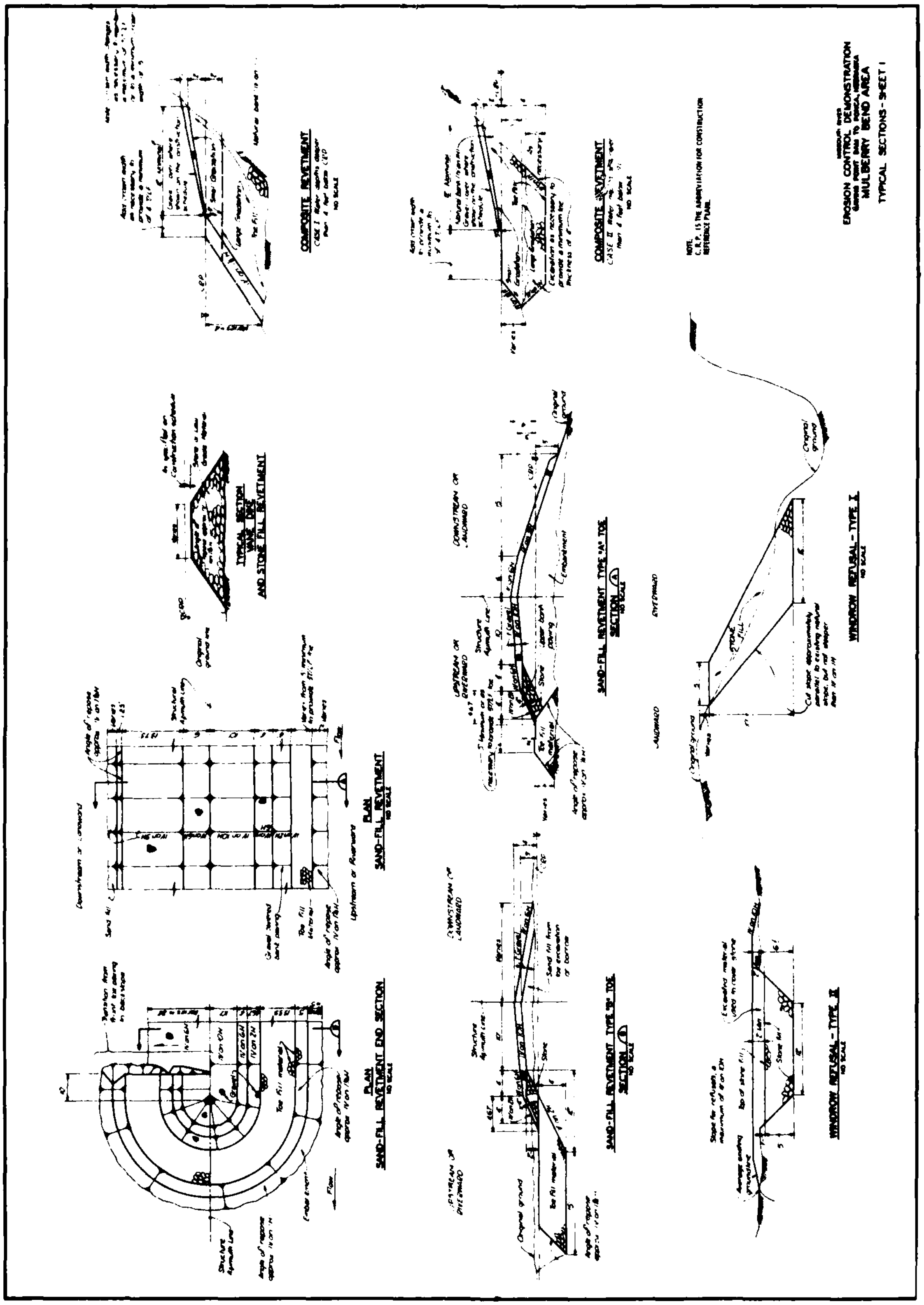
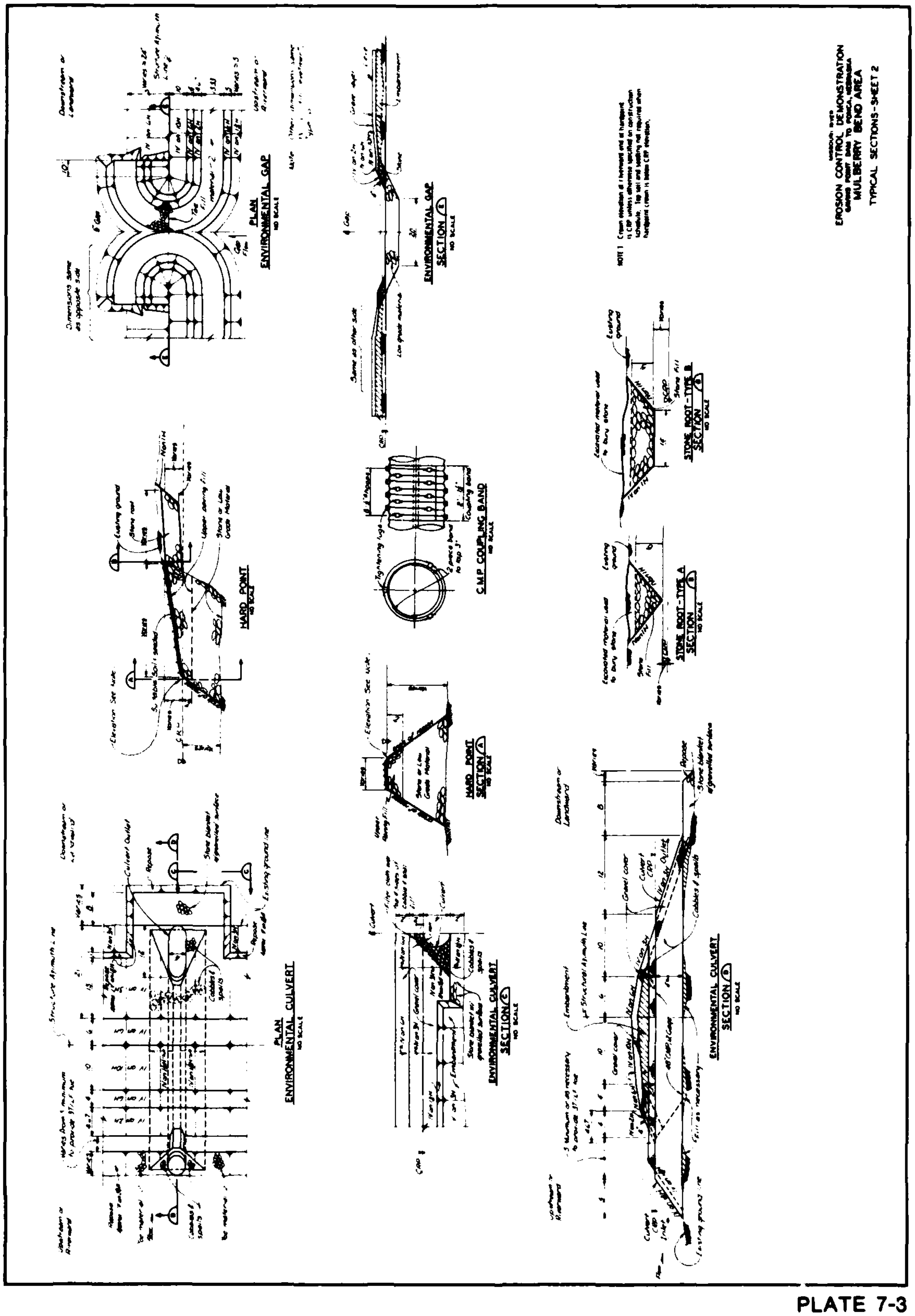

EROSION CONTROL DEMONSTRATION
MULBERRY BEND AREA
TYPICAL SECTIONS - SHEET I
COMPOSITE REVETMENT
TYPICAL SECTION
STONE FILL REVETMENT
PLAN
SAND-FILL REVETMENT
SAND-FILL REVETMENT TYPE "A" TOE
SECTION A
SAND-FILL REVETMENT TYPE "B" TOE
SECTION B
SAND-FILL REVETMENT END SECTION
WINDROW REFUSAL - TYPE I
WINDROW REFUSAL - TYPE II
NO SCALE

PLATE 7-2



EROSION CONTROL DEMONSTRATION
MULBERRY BEND AREA
TYPICAL SECTIONS-SHEET 2
PLAN ENVIRONMENTAL GAP
ENVIRONMENTAL GAP SECTION
HARD POINT
C.M.P. COUPLING BAND
STONE ROOT-TYPE B SECTION
STONE ROOT-TYPE A SECTION
PLAN ENVIRONMENTAL CULVERT
ENVIRONMENTAL CULVERT SECTION
HARD POINT SECTION
ENVIRONMENTAL CULVERT SECTION

PLATE 7-3

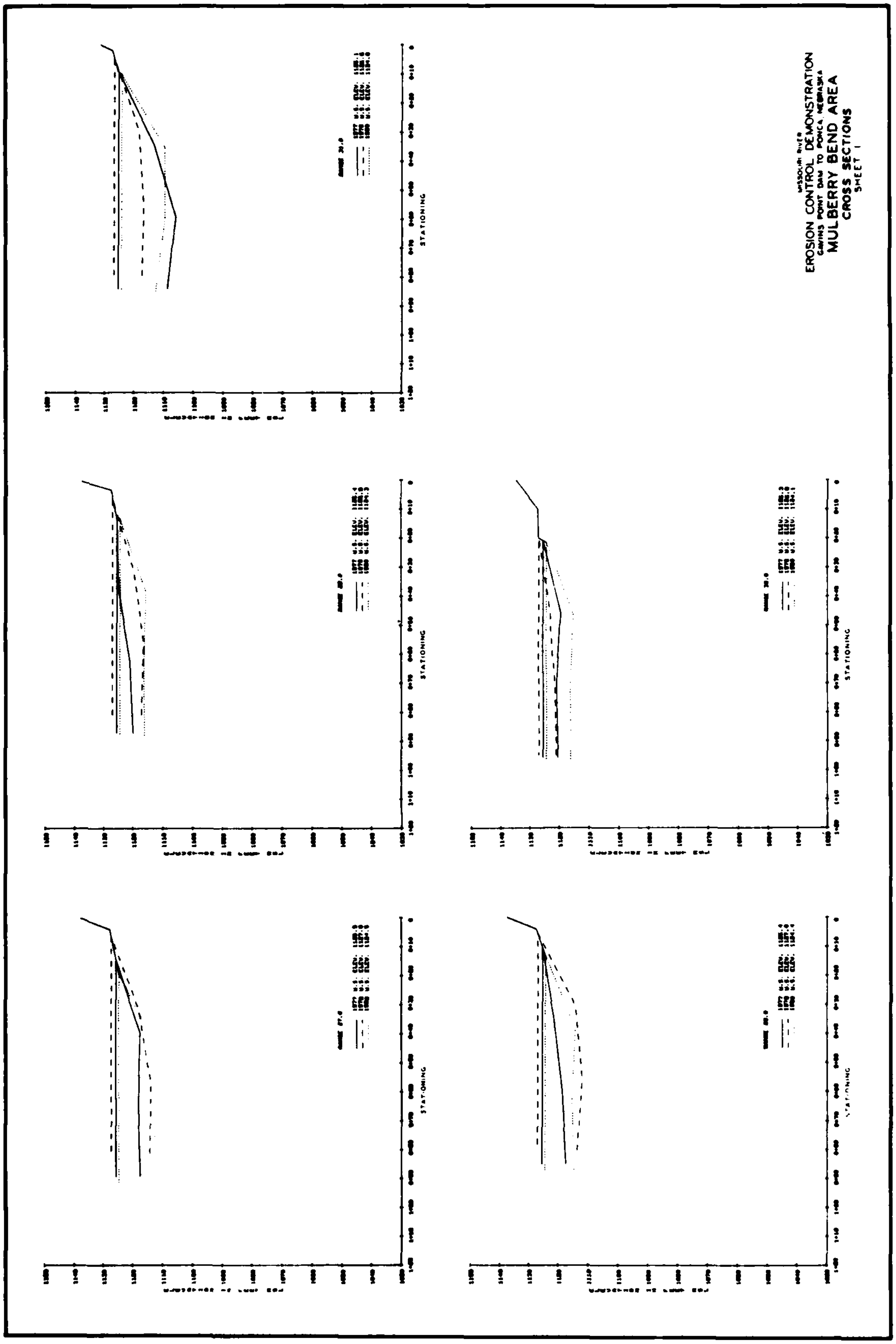
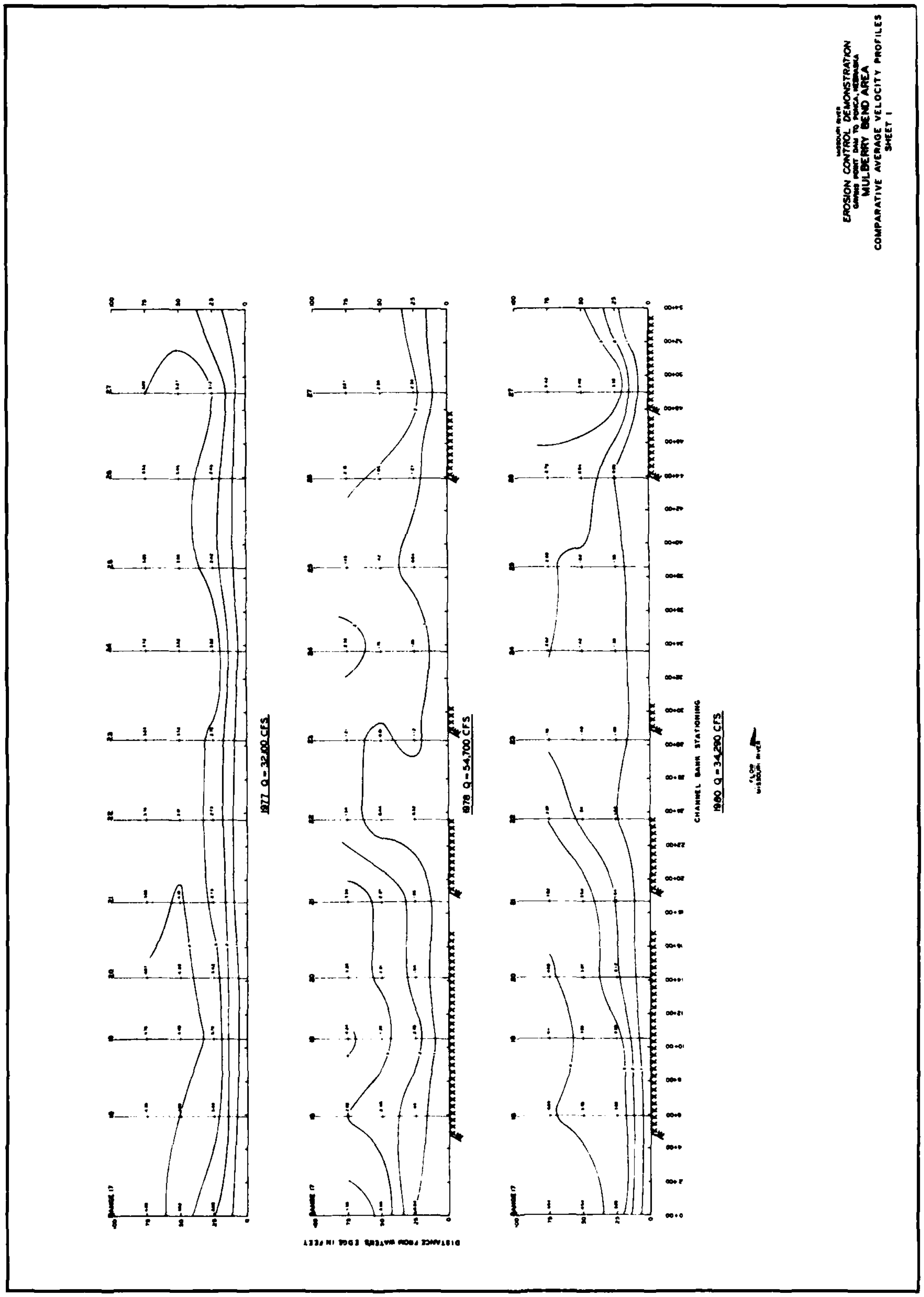
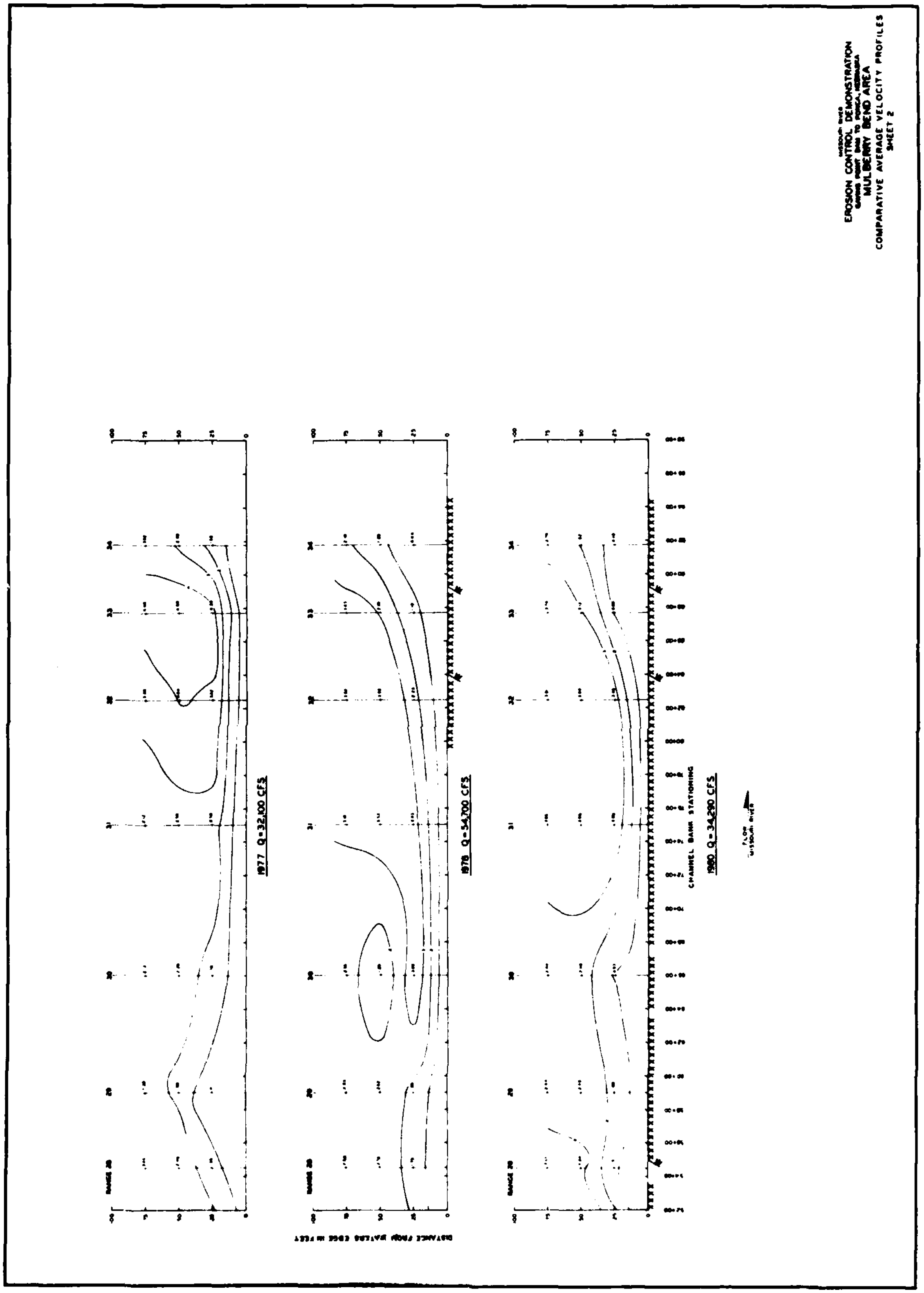

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA NEBRASKA
MULBERRY BEND AREA
CROSS SECTIONS
SHEET 1
STATIONING

PLATE 7-4



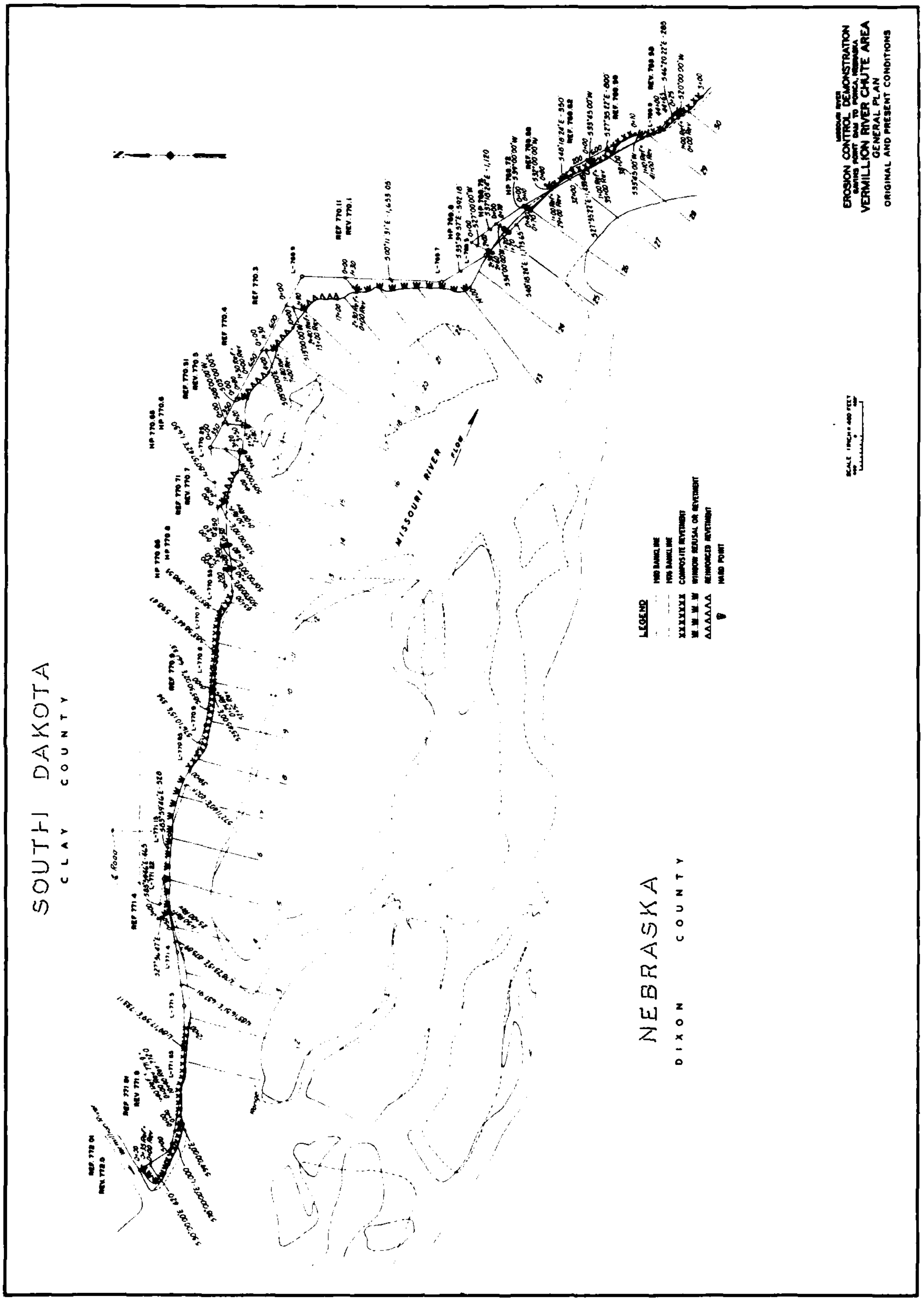
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
MULBERRY BEND AREA
COMPARATIVE AVERAGE VELOCITY PROFILES
SHEET 1
1977 Q = 32,100 CFS
1978 Q = 54,700 CFS
1980 Q = 34,290 CFS
CHANNEL BANK STATIONING
DISTANCE FROM WATERS EDGE IN FEET

PLATE 7-5



MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
MULBERRY BEND AREA
COMPARATIVE AVERAGE VELOCITY PROFILES
SHEET 2
1977 Q=32,100 CFS
1978 Q=34,700 CFS
1980 Q=34,290 CFS
CHANNEL BANK STATIONING
DISTANCE FROM WATERS EDGE IN FEET
FLOW
MISSOURI RIVER

PLATE 7-6



MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
VERMILLION RIVER CHUTE AREA
GENERAL PLAN
ORIGINAL AND PRESENT CONDITIONS
SOUTH DAKOTA
CLAY COUNTY
NEBRASKA
DIXON COUNTY
MISSOURI RIVER
FLOW
LEGEND

PLATE 8-1

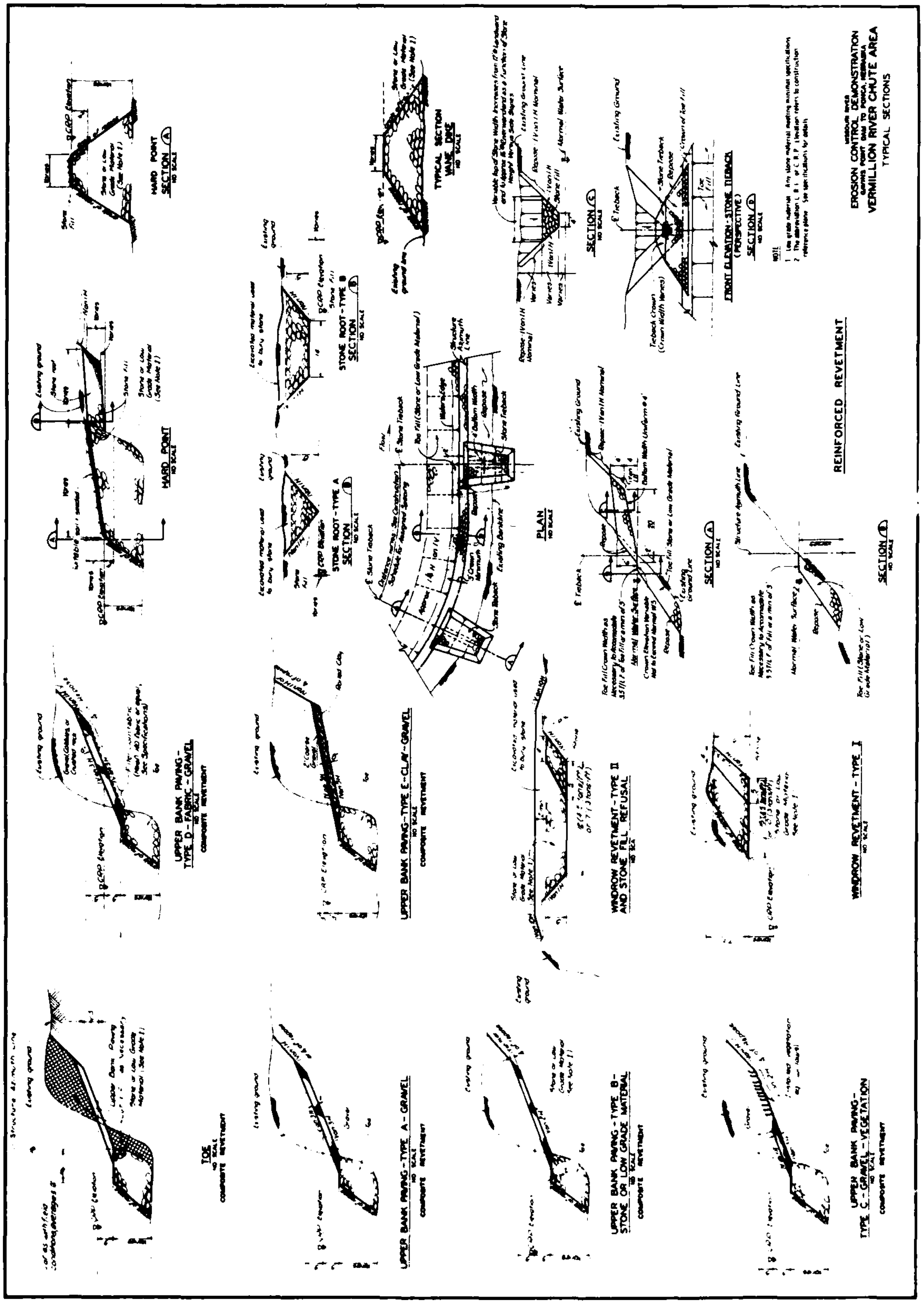
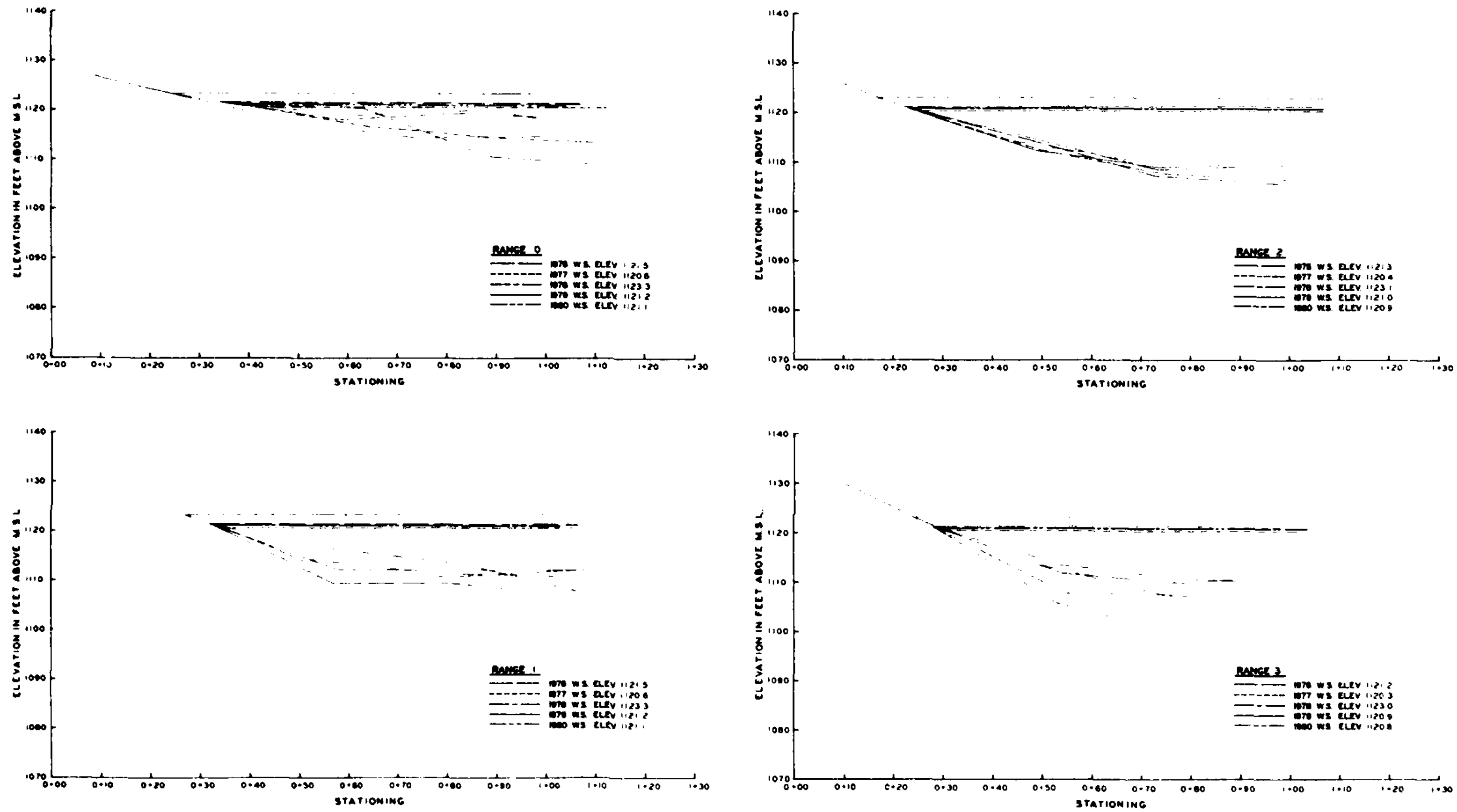

EROSION CONTROL DEMONSTRATION
VERMILLION RIVER CHUTE AREA
TYPICAL SECTIONS
REINFORCED REVETMENT
HARD POINT
SECTION A
STONE ROOT - TYPE A
STONE ROOT - TYPE B
TYPICAL SECTION VANE DIKE
PLAN
UPPER BANK PAVING - TYPE D - FABRIC - GRAVEL
UPPER BANK PAVING - TYPE E - CLAY - GRAVEL
WINDROW REVETMENT - TYPE II AND STONE FILL REFUSAL
WINDROW REVETMENT - TYPE I
TOE
UPPER BANK PAVING - TYPE A - GRAVEL
UPPER BANK PAVING - TYPE B - STONE OR LOW GRADE MATERIAL
UPPER BANK PAVING - TYPE C - GRAVEL - VEGETATION
FRONT ELEVATION - STONE TIEBACK

PLATE 8-2



MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
VERMILLION RIVER CHUTE AREA
CROSS SECTIONS
SHEET 1

PLATE 8-3

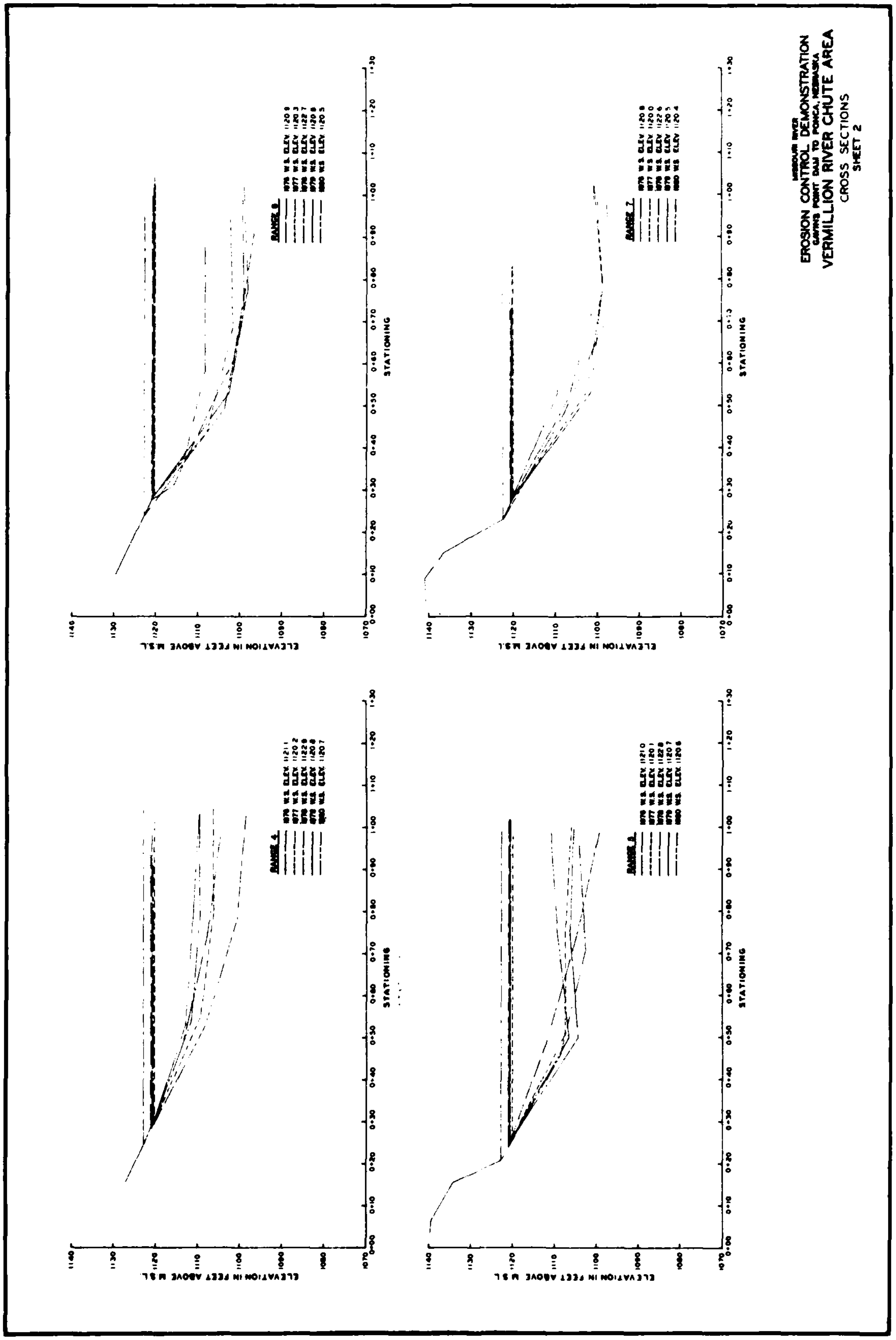

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
VERMILLION RIVER CHUTE AREA
CROSS SECTIONS
SHEET 2
ELEVATION IN FEET ABOVE M.S.L.
STATIONING

PLATE 8-4

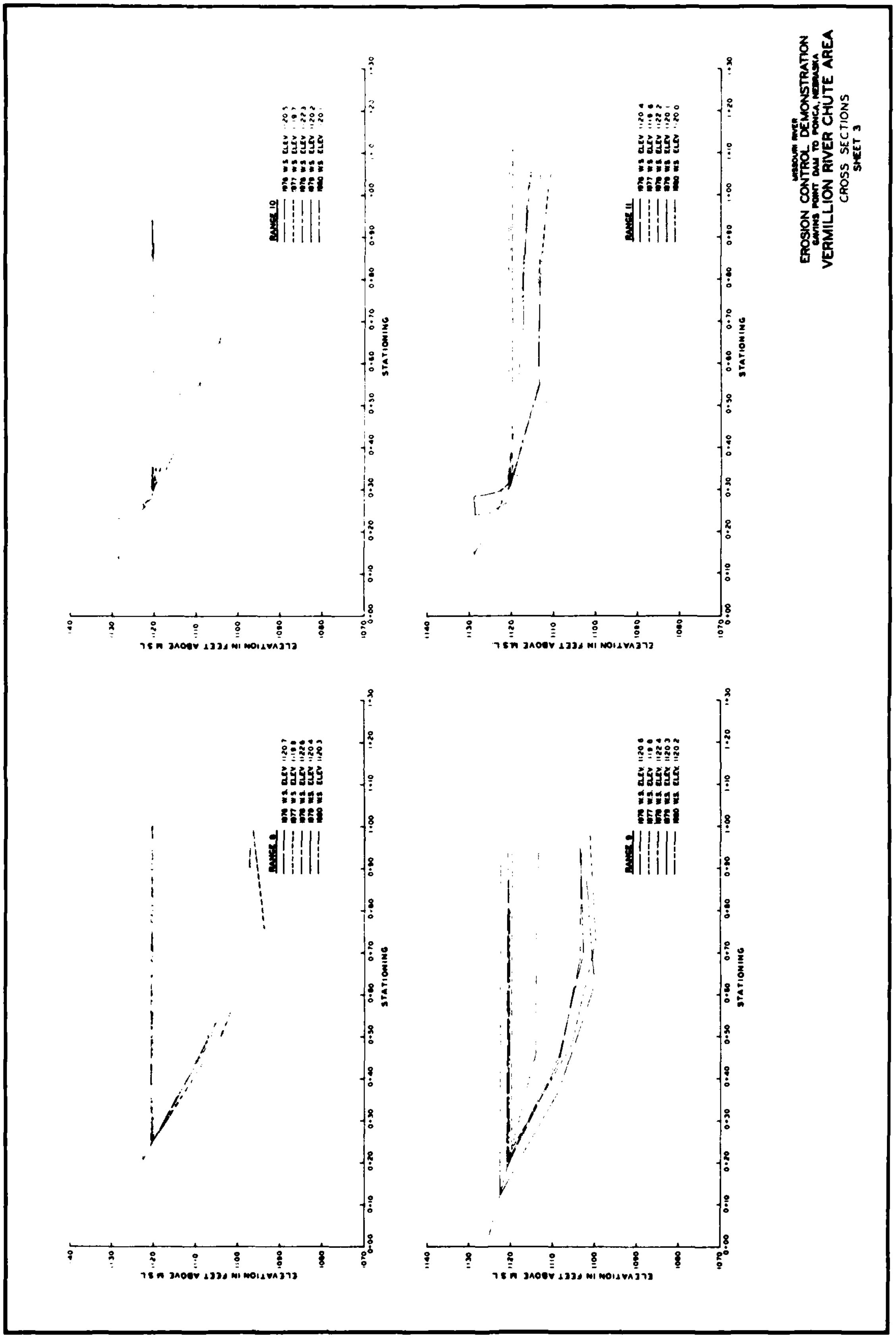

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
VERMILLION RIVER CHUTE AREA
CROSS SECTIONS
SHEET 3
RANGE 8
RANGE 9
RANGE 10
RANGE 11
STATIONING
ELEVATION IN FEET ABOVE M.S.L.

PLATE 8-5

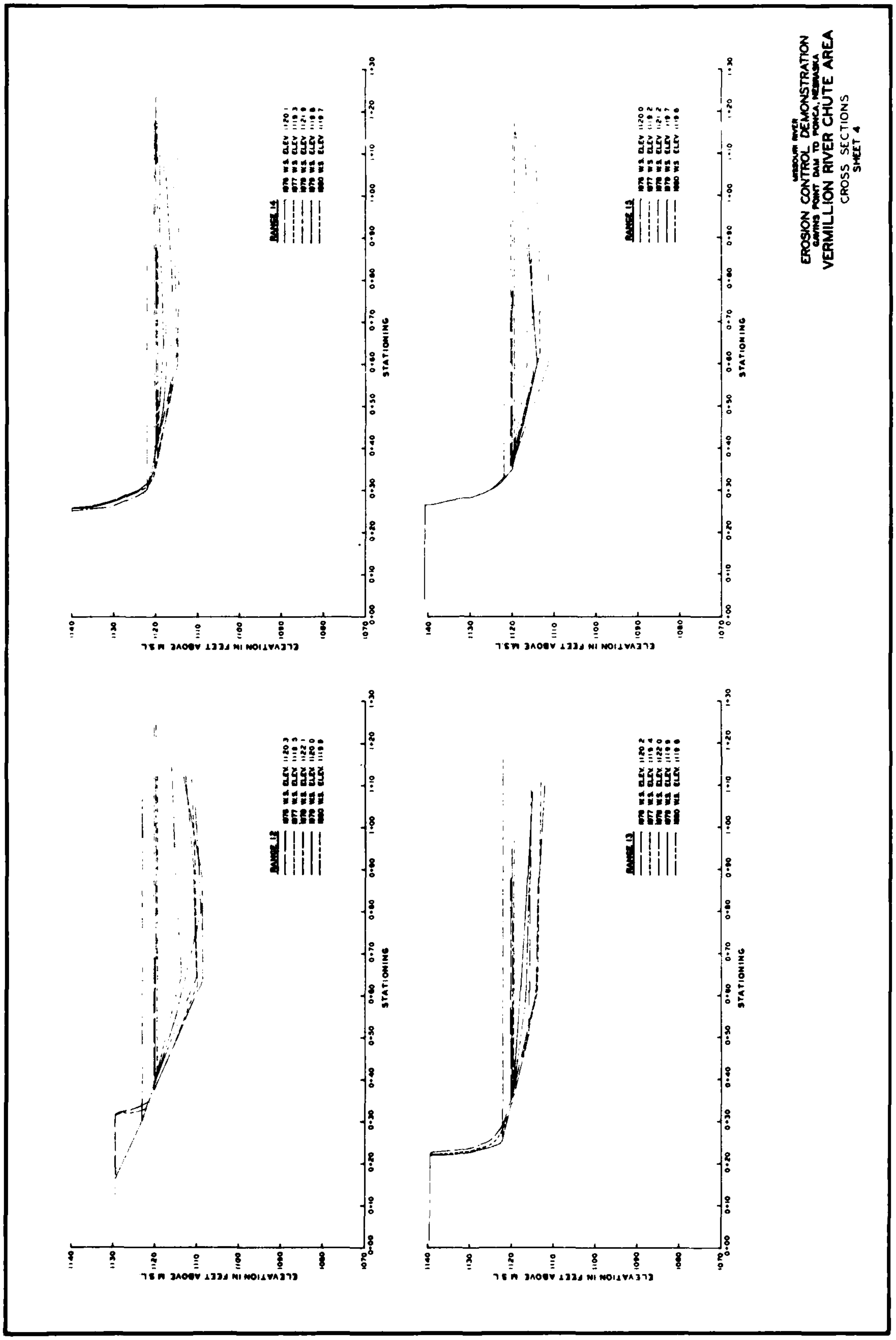

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
VERMILLION RIVER CHUTE AREA
CROSS SECTIONS
SHEET 4
STATIONING
ELEVATION IN FEET ABOVE M.S.L.

PLATE 8-6

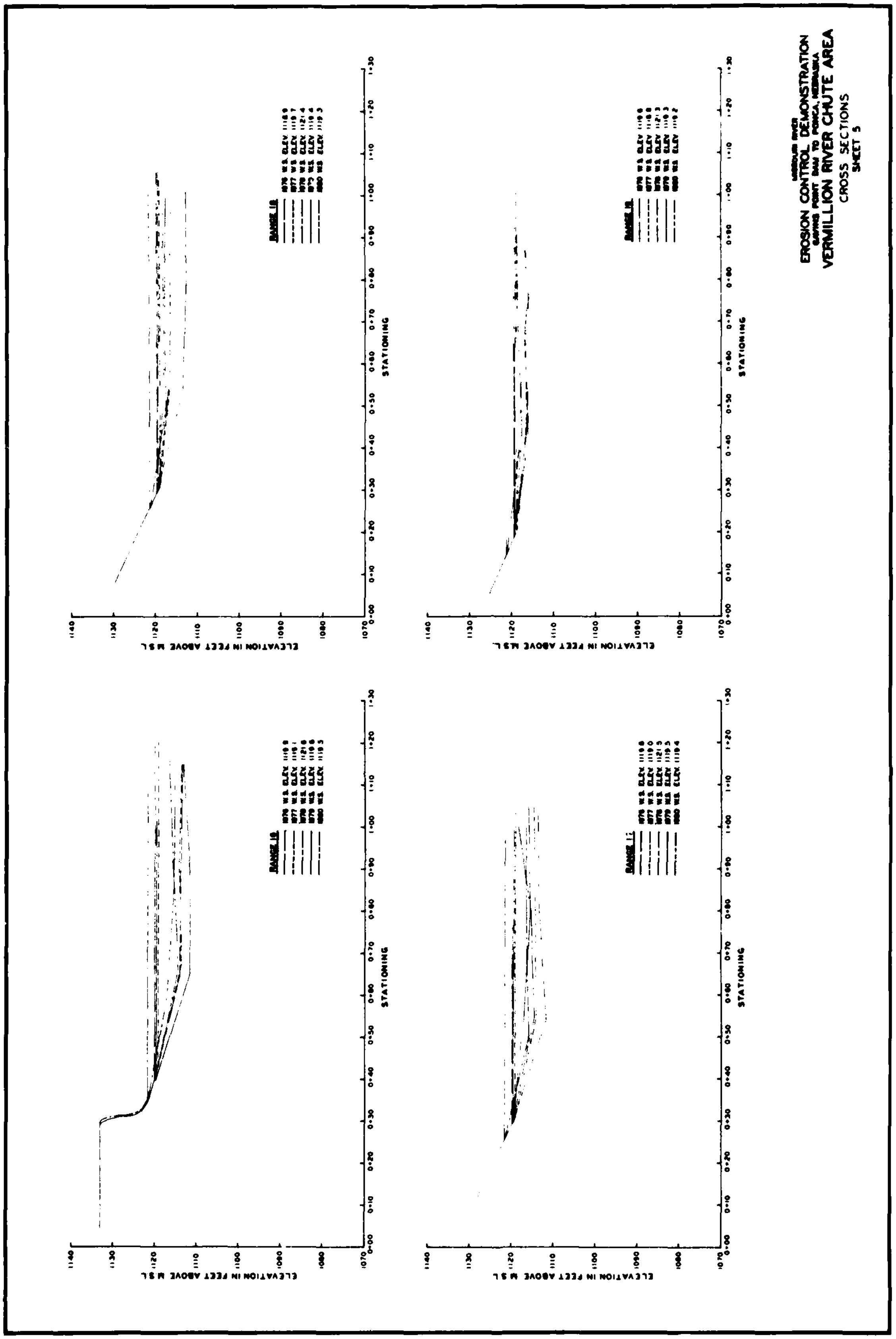

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
VERMILLION RIVER CHUTE AREA
CROSS SECTIONS
SHEET 5

PLATE 8-7

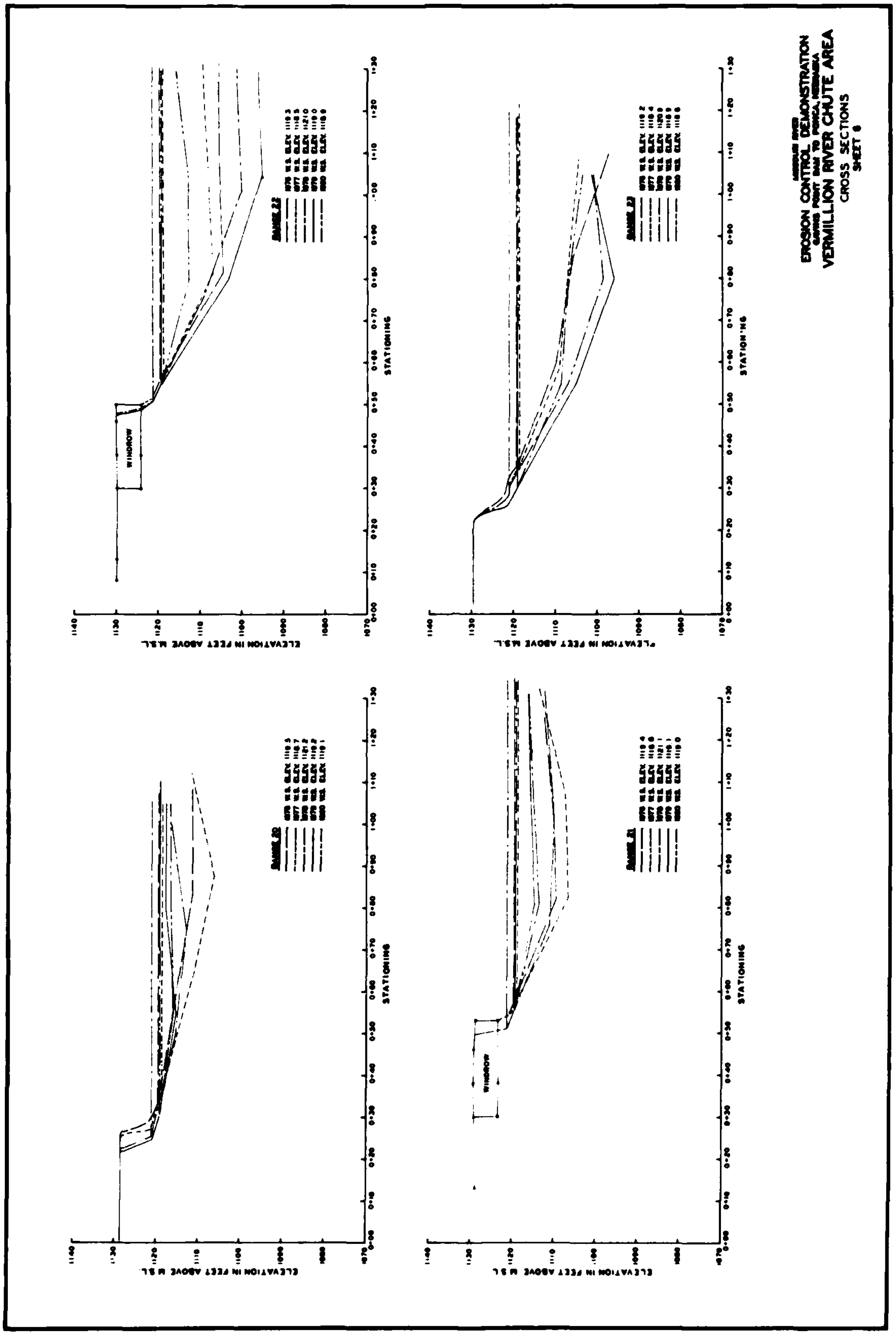

EROSION CONTROL DEMONSTRATION
VERMILLION RIVER CHUTE AREA
CROSS SECTIONS
WINDROW
STATIONING
ELEVATION IN FEET ABOVE M.S.L.

PLATE 8-8

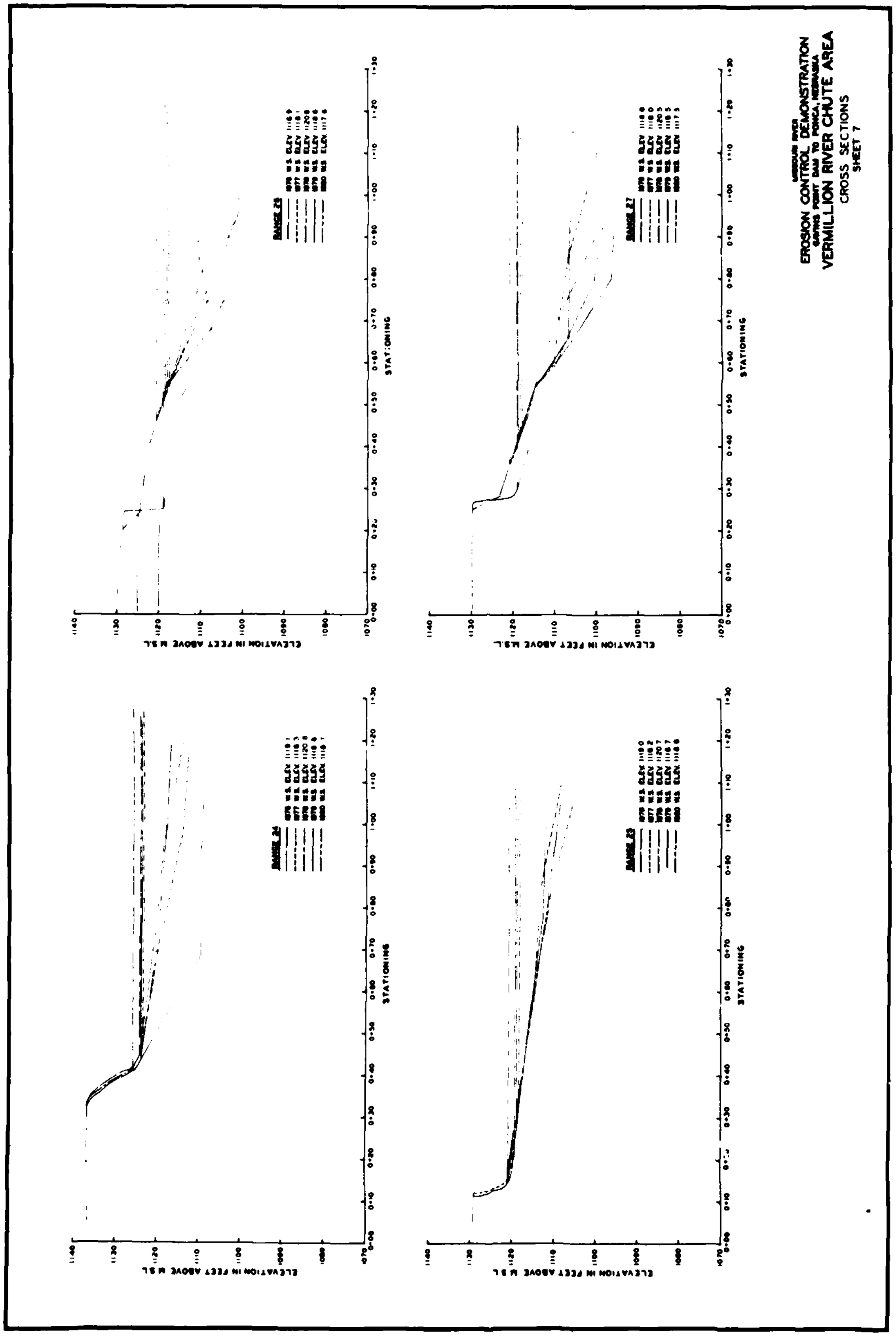

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
VERMILLION RIVER CHUTE AREA
CROSS SECTIONS
SHEET 7
ELEVATION IN FEET ABOVE M.S.L.
STATIONING

PLATE 8-9

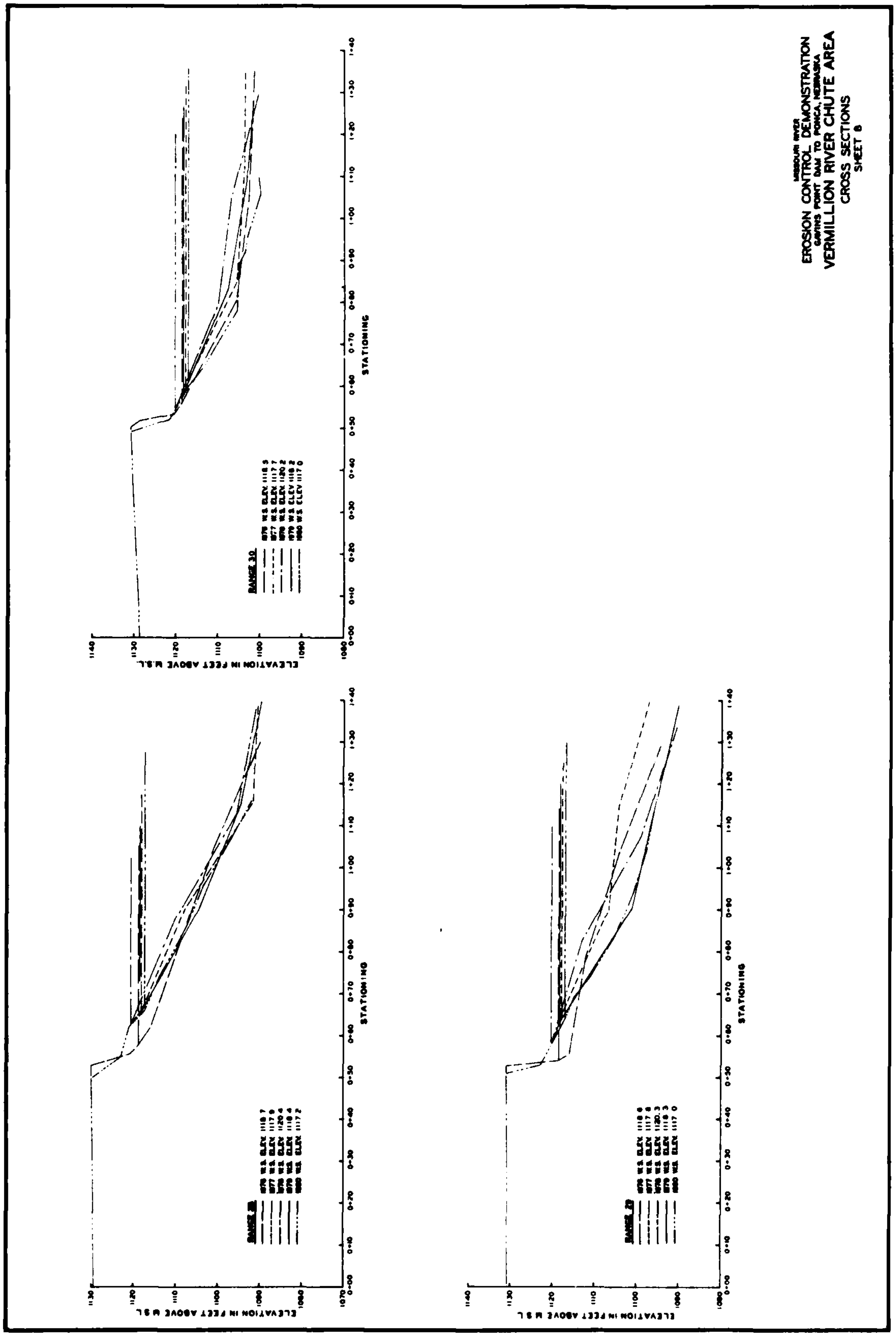
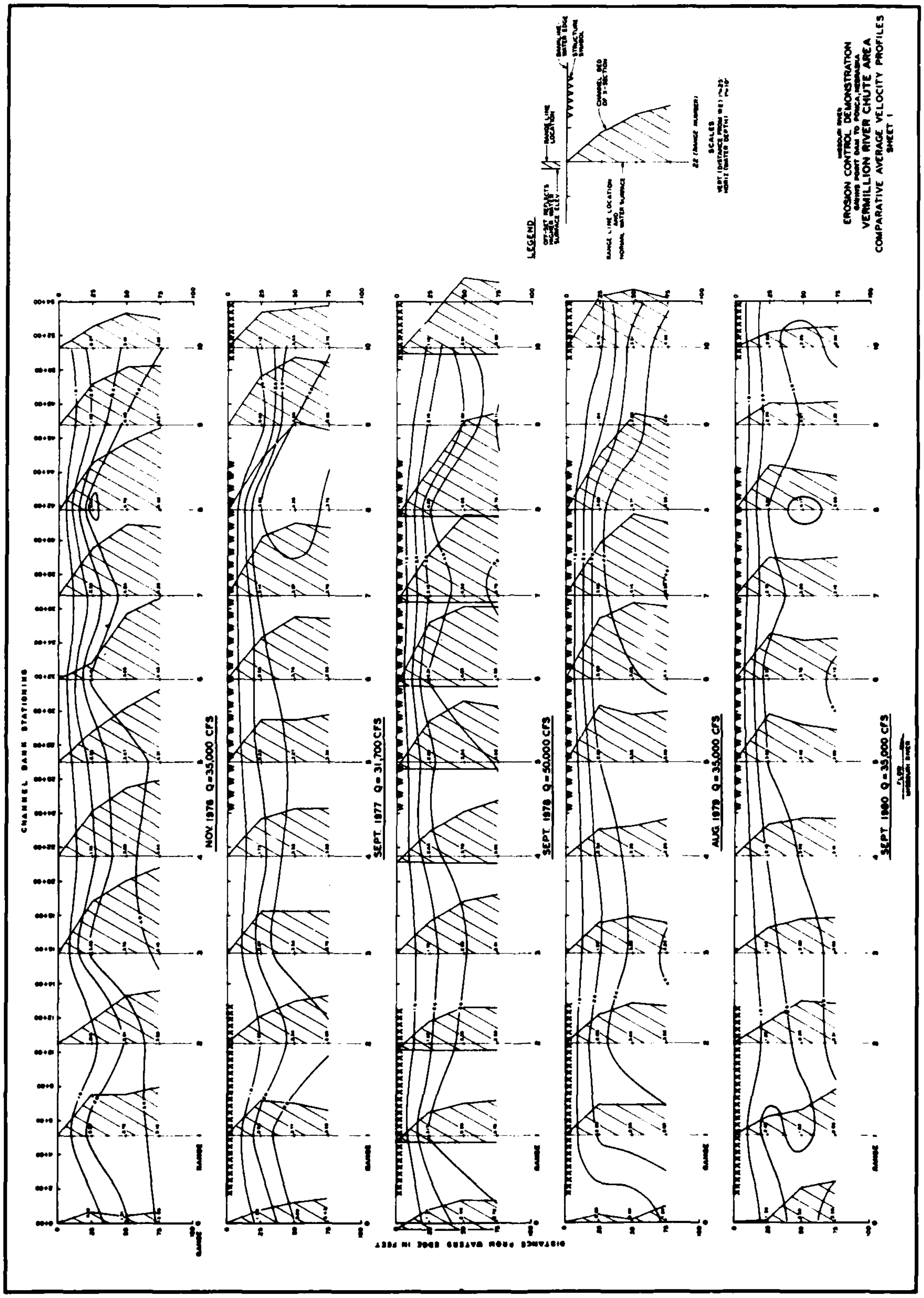
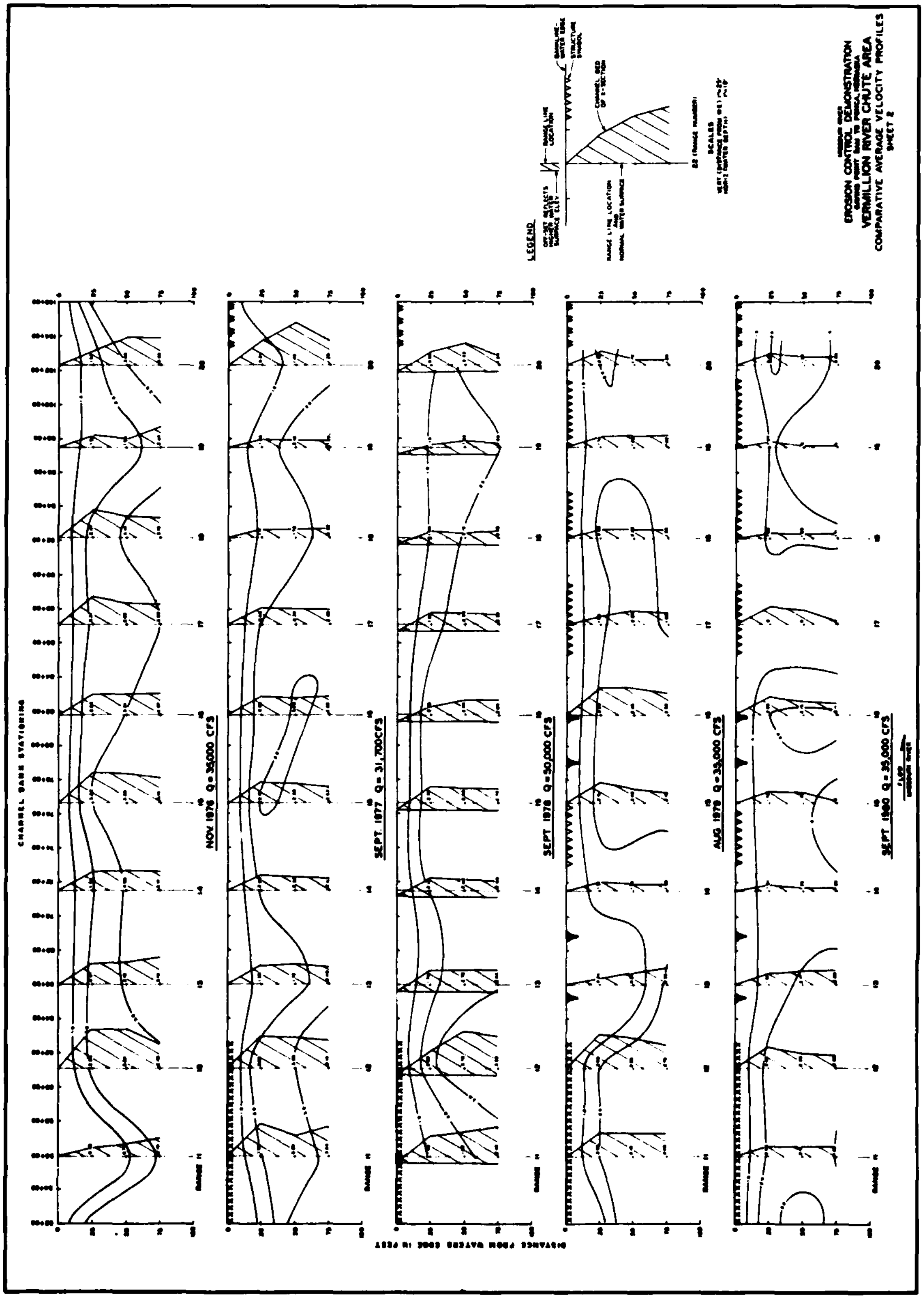

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
VERMILLION RIVER CHUTE AREA
CROSS SECTIONS
SHEET 8
STATIONING
ELEVATION IN FEET ABOVE M.S.L.

PLATE 8-10



MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
VERMILLION RIVER CHUTE AREA
COMPARATIVE AVERAGE VELOCITY PROFILES
SHEET 1
LEGEND
CHANNEL BANK STATIONING
SEPT. 1977 Q=31,700 CFS
SEPT. 1978 Q=50,000 CFS
AUG. 1979 Q=35,000 CFS
SEPT. 1980 Q=35,000 CFS
DISTANCE FROM WATERS EDGE IN FEET

PLATE 8-11



LEGEND
EROSION CONTROL DEMONSTRATION
VERMILLION RIVER CHUTE AREA
COMPARATIVE AVERAGE VELOCITY PROFILES
SHEET 2
CHANNEL BANK STATIONING
NOV 1976 Q = 35,000 CFS
SEPT. 1977 Q = 31,700 CFS
SEPT 1978 Q = 50,000 CFS
AUG 1979 Q = 35,000 CFS
SEPT 1980 Q = 35,000 CFS
DISTANCE FROM WATERS EDGE IN FEET

PLATE 8-12

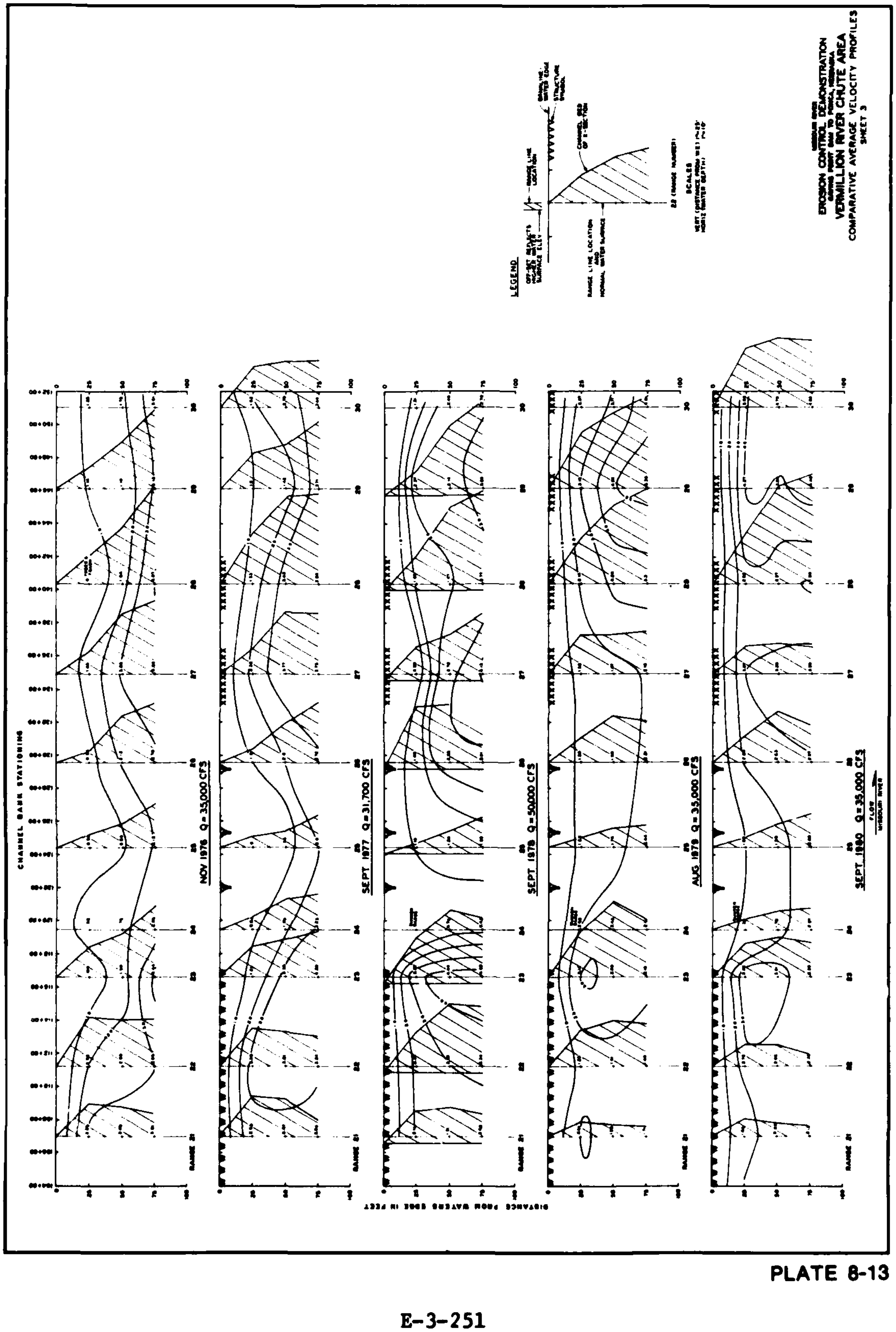
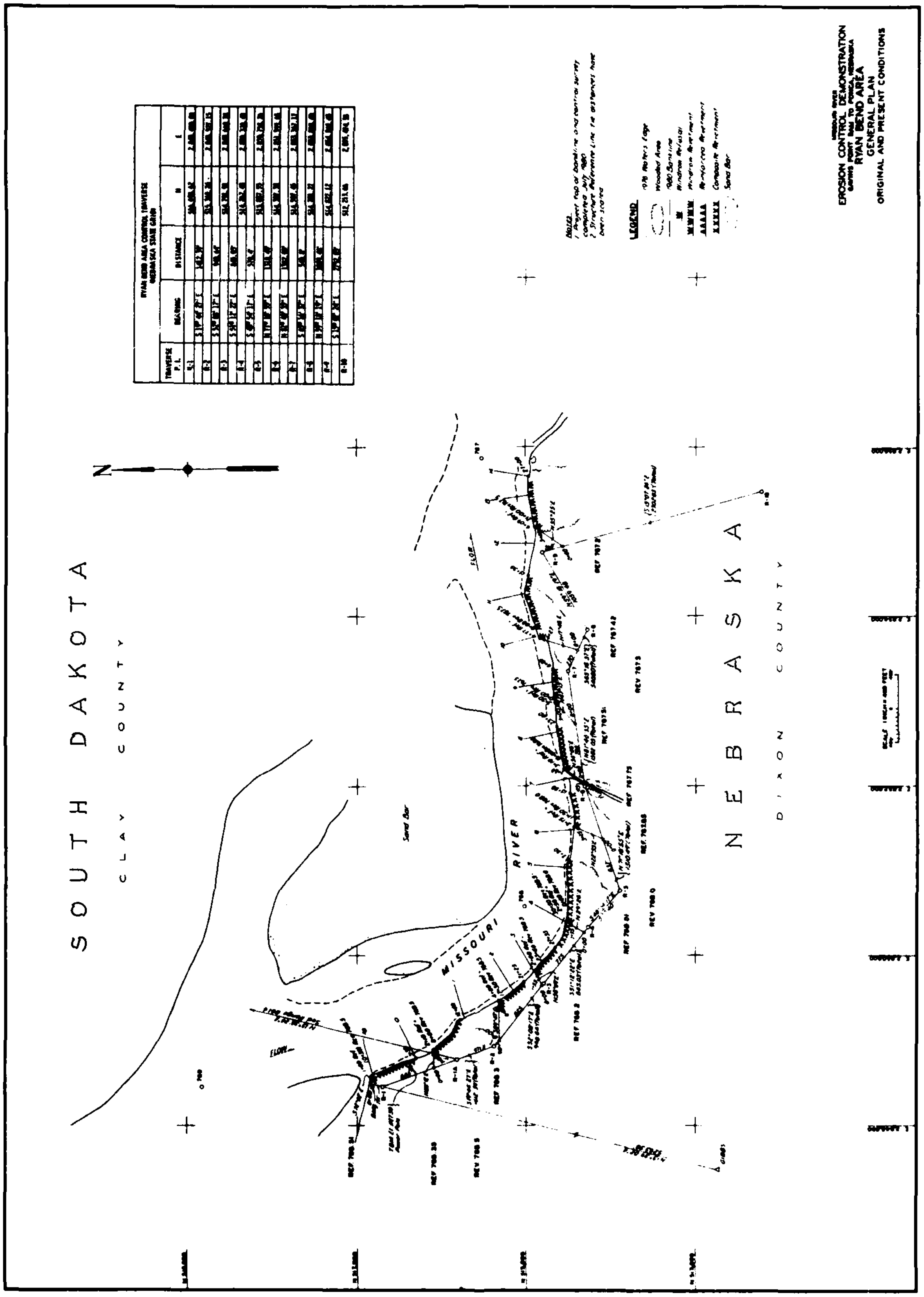
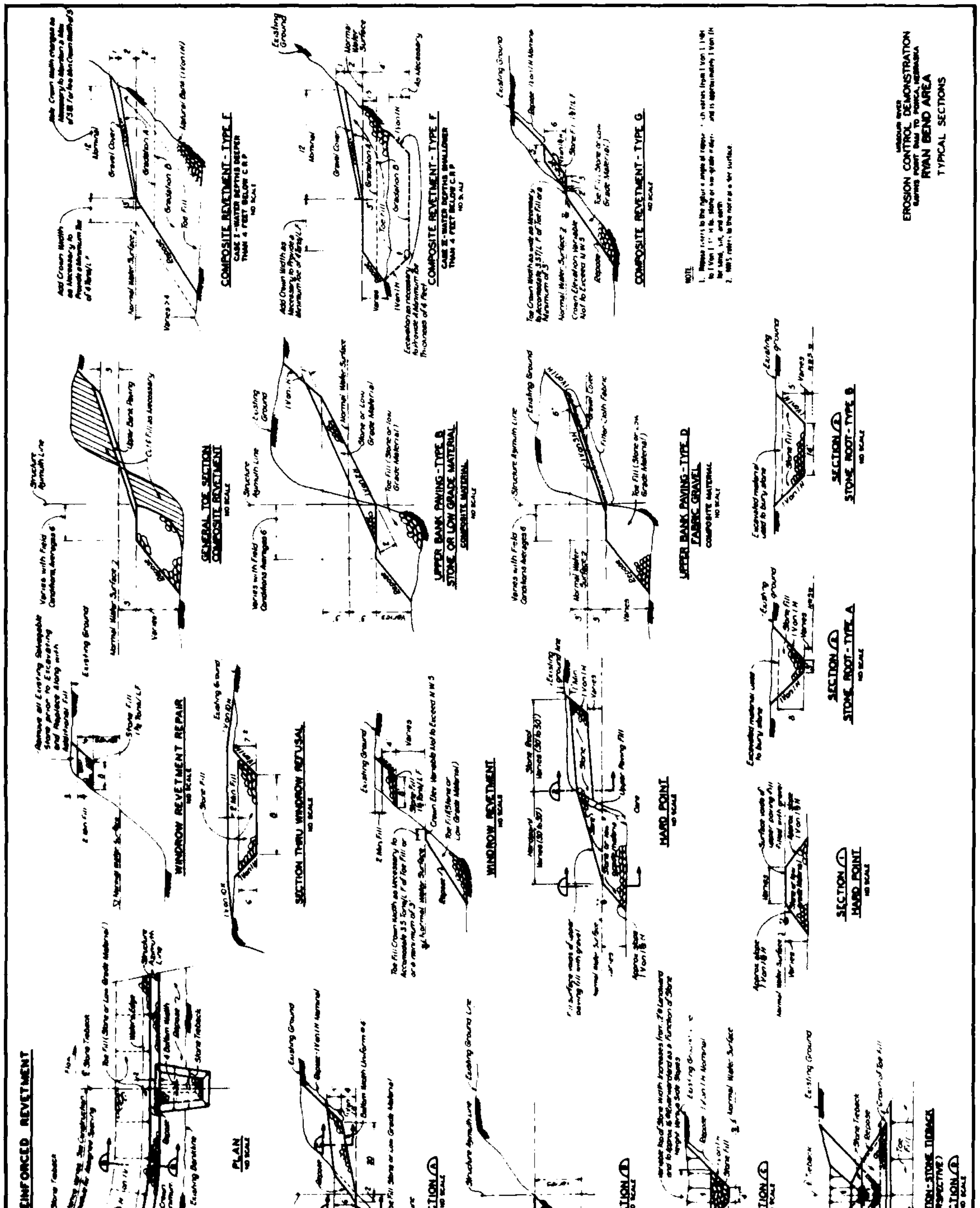

EROSION CONTROL DEMONSTRATION
VERMILLION RIVER CHUTE AREA
COMPARATIVE AVERAGE VELOCITY PROFILES
SHEET 3
LEGEND
CHANNEL BANK STATIONING
NOV 1976 Q=35,000 CFS
SEPT 1977 Q=31,700 CFS
SEPT 1978 Q=50,000 CFS
AUG 1979 Q=35,000 CFS
SEPT 1980 Q=35,000 CFS
DISTANCE FROM WATERS EDGE IN FEET

PLATE 8-13



SOUTH DAKOTA
CLAY COUNTY
NEBRASKA
DIXON COUNTY
MISSOURI RIVER
Sand Bar
FLOW
RYAN BEND AREA CONTROL TRAVERSE
NEBRASKA STATE GRID
TRAVERSE P.I.
BEARING
DISTANCE
N
E
NOTES
1 Project top of bankline and control survey completed July 1980
2 Structure Reference Line tie distances have been scaled
LEGEND
1978 Waters Edge
Wooded Area
1980 Bankline
Windrow Revetment
Composite Revetment
Sand Bar
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
RYAN BEND AREA
GENERAL PLAN
ORIGINAL AND PRESENT CONDITIONS

PLATE 9-1



REINFORCED REVETMENT
WINDROW REVETMENT REPAIR
GENERAL TOE SECTION COMPOSITE REVETMENT
COMPOSITE REVETMENT - TYPE F
SECTION THRU WINDROW REFUSAL
WINDROW REVETMENT
HARD POINT
UPPER BANK PAVING - TYPE D
COMPOSITE REVETMENT - TYPE G
STONE ROOT - TYPE A
STONE ROOT - TYPE B
EROSION CONTROL DEMONSTRATION
RYAN BEND AREA
TYPICAL SECTIONS

PLATE 9-2

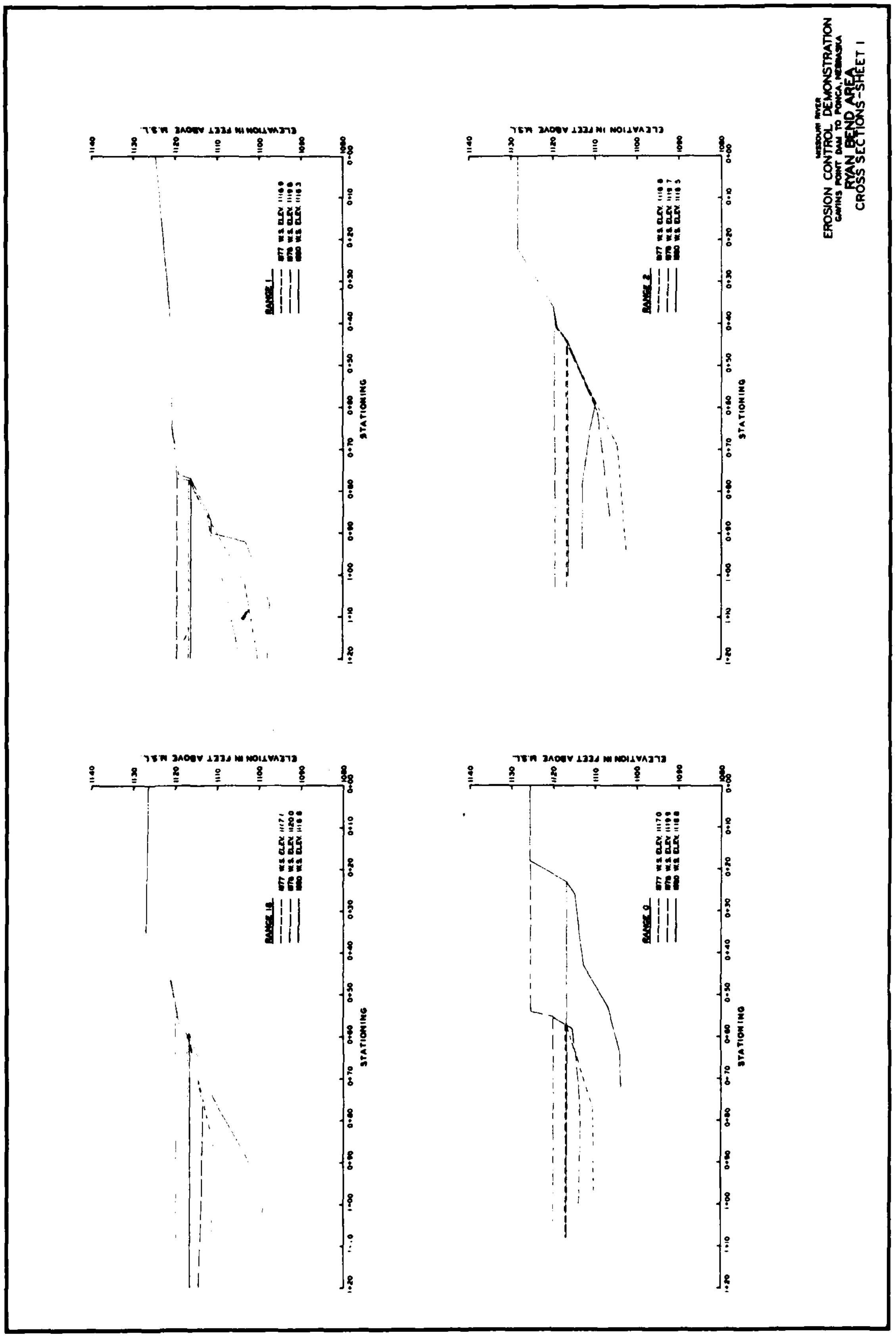

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
RYAN BEND AREA
CROSS SECTIONS-SHEET 1
RANGE 1
RANGE 2
RANGE 1B
RANGE 0
ELEVATION IN FEET ABOVE M.S.L.
STATIONING

PLATE 9-3

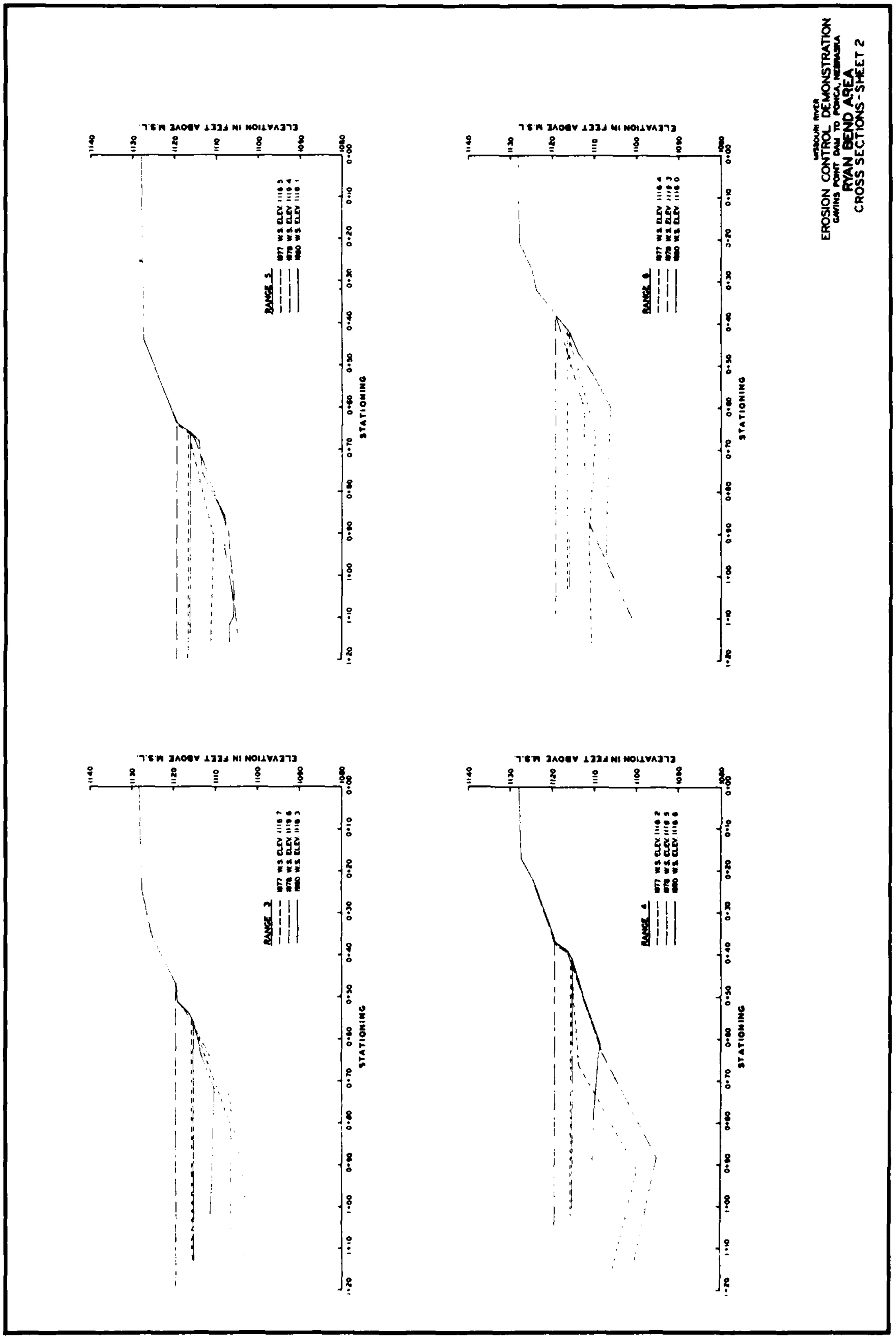

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
RYAN BEND AREA
CROSS SECTIONS - SHEET 2
RANGE 5
RANGE 6
RANGE 3
RANGE 4
ELEVATION IN FEET ABOVE M.S.L.
STATIONING

PLATE 9-4

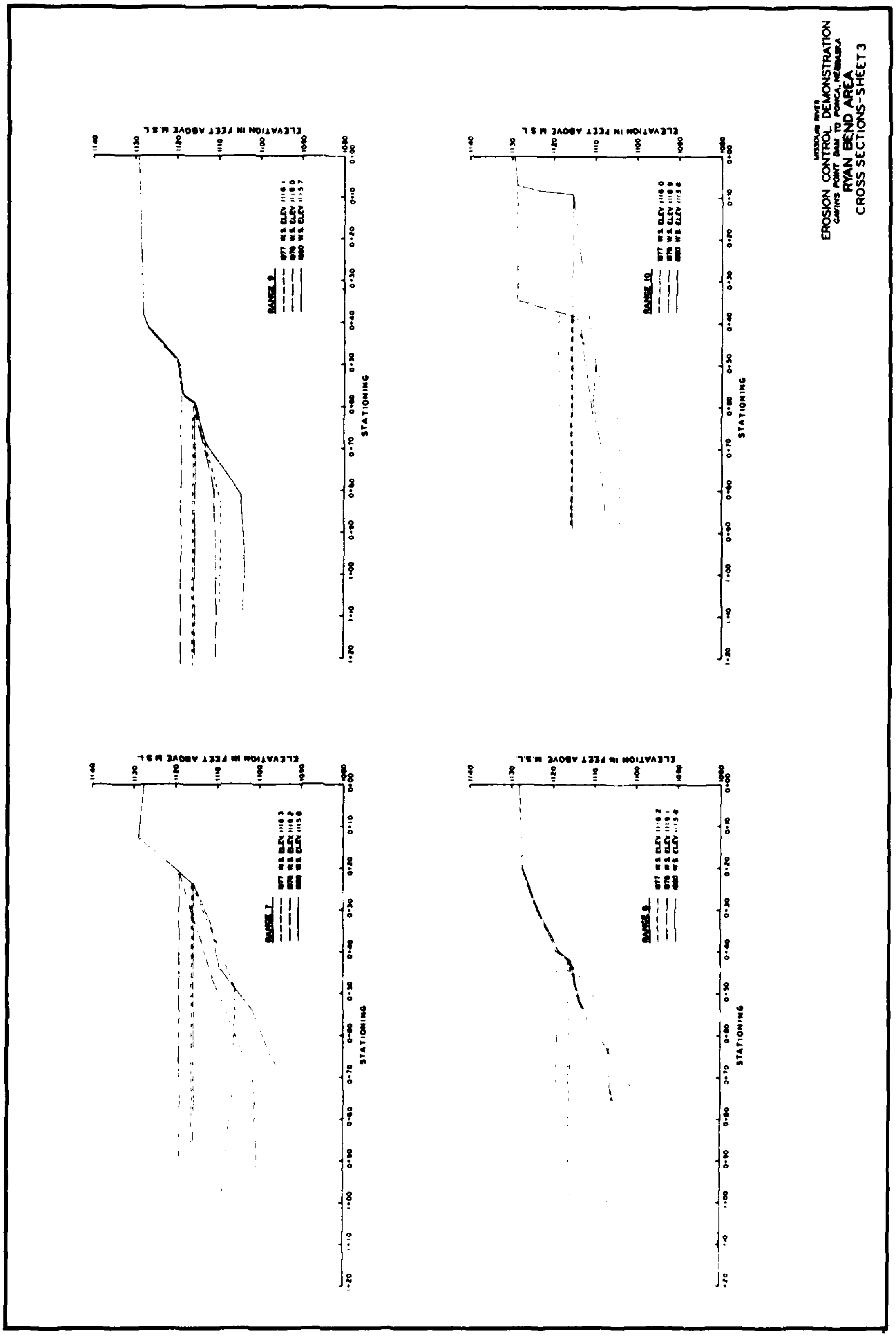
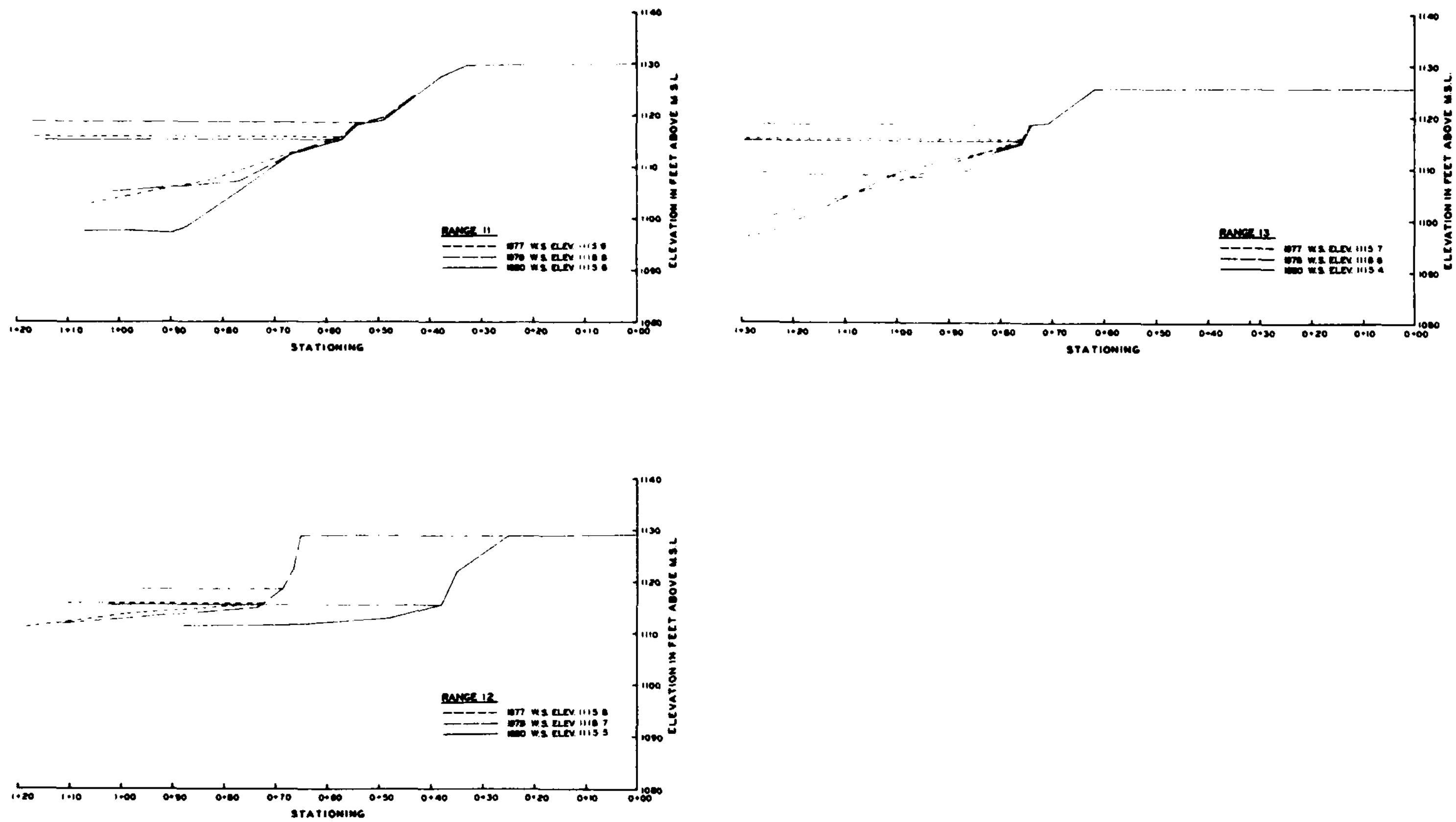
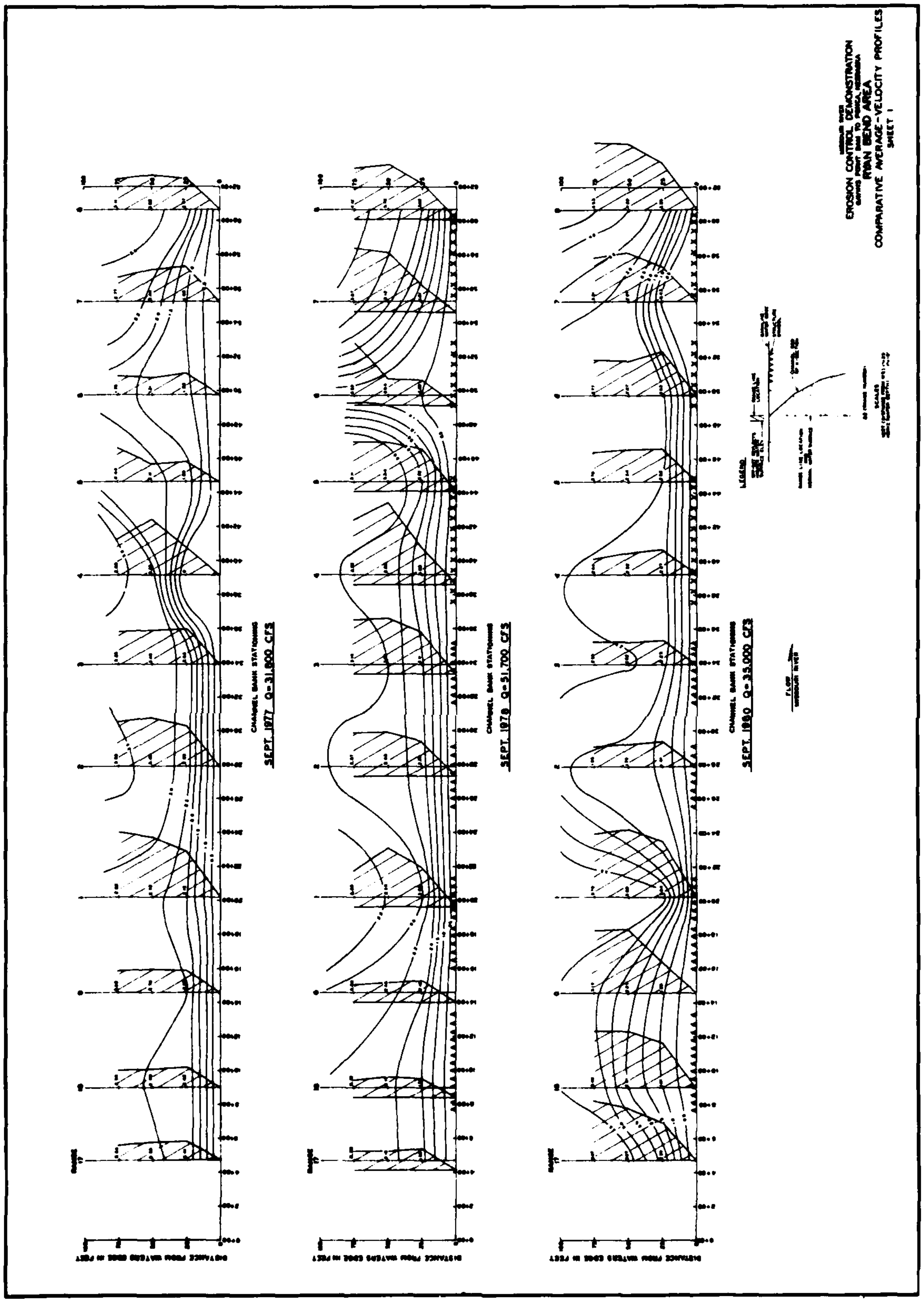

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
RYAN BEND AREA
CROSS SECTIONS-SHEET 3
STATIONING
ELEVATION IN FEET ABOVE M.S.L.

PLATE 9-5



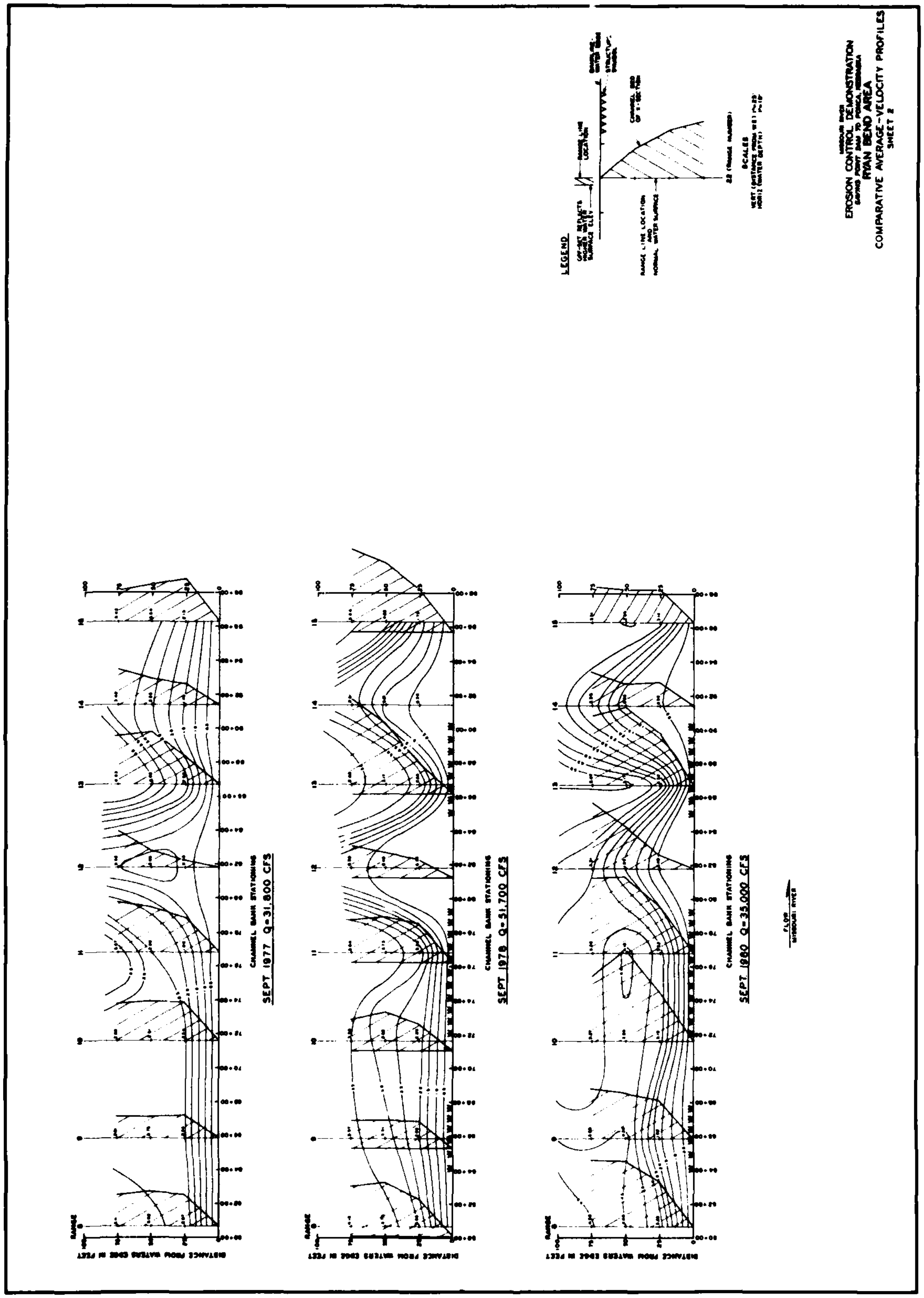
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
RYAN BEND AREA
CROSS SECTIONS-SHEET 4

PLATE 9-6



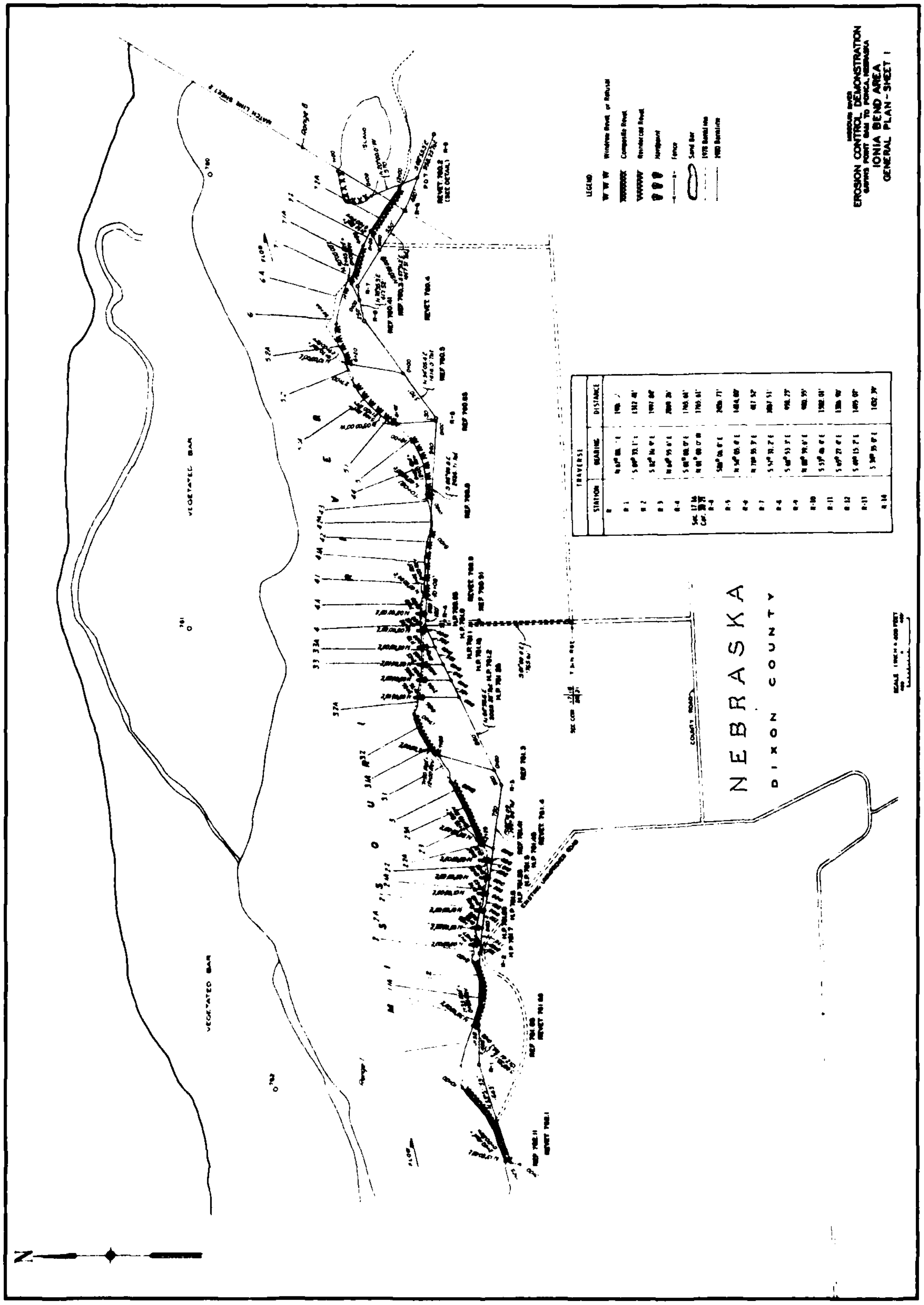
EROSION CONTROL DEMONSTRATION
RYAN BEND AREA
COMPARATIVE AVERAGE-VELOCITY PROFILES
SHEET 1
SEPT. 1977 Q=31,800 CFS
SEPT. 1978 Q=51,700 CFS
SEPT. 1980 Q=35,000 CFS

PLATE 9-7



LEGEND
EROSION CONTROL DEMONSTRATION
RYAN BEND AREA
COMPARATIVE AVERAGE-VELOCITY PROFILES
SHEET 2
SEPT 1977 Q=31,800 CFS
SEPT 1978 Q=31,700 CFS
SEPT 1980 Q=35,000 CFS
CHANNEL BANK STATIONING
DISTANCE FROM WATERS EDGE IN FEET

PLATE 9-8



EROSION CONTROL DEMONSTRATION
IONIA BEND AREA
GENERAL PLAN - SHEET 1
LEGEND
TRAVERSE
STATION
BEARING
DISTANCE
VEGETATED BAR
VEGETATED BAR
NEBRASKA
DIXON COUNTY

PLATE 10-1

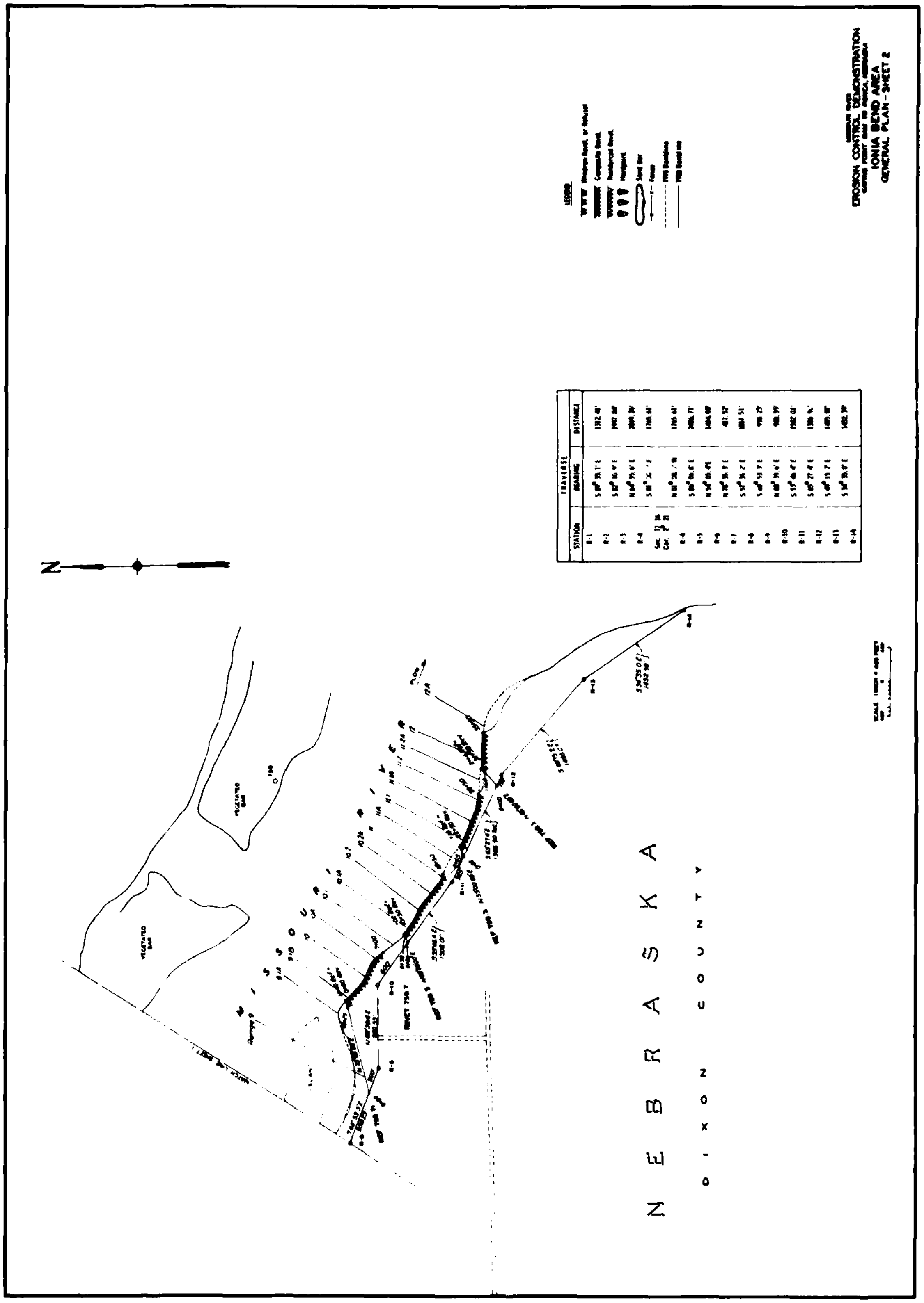

EROSION CONTROL DEMONSTRATION
IONIA BEND AREA
GENERAL PLAN - SHEET 2
TRAVERSE
STATION
BEARING
DISTANCE
N
NEBRASKA
DIXON COUNTY

PLATE 10-2

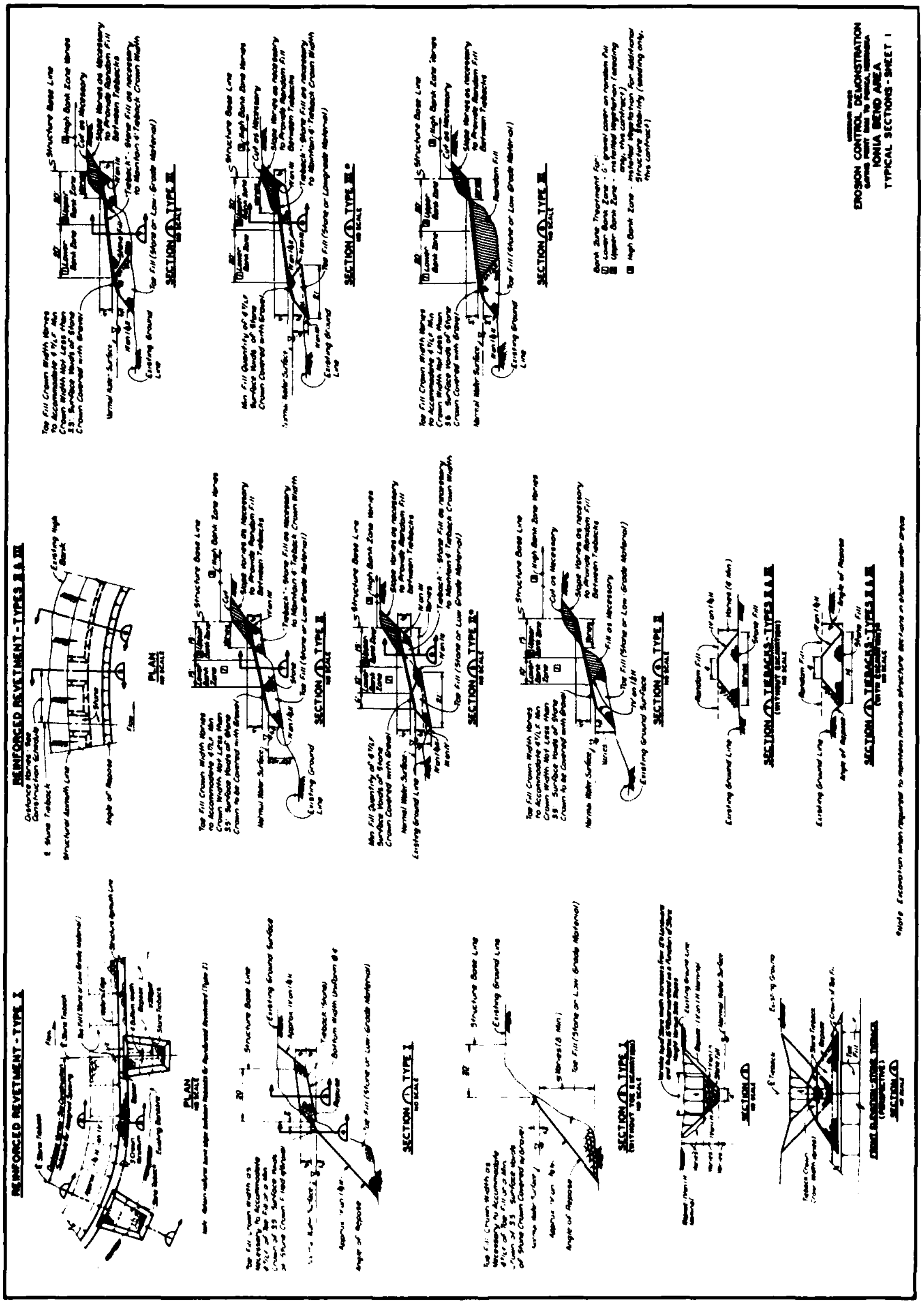

REINFORCED REVETMENT - TYPE I
REINFORCED REVETMENT - TYPES II & III
EROSION CONTROL DEMONSTRATION
IONIA BEND AREA
TYPICAL SECTIONS - SHEET 1

PLATE 10-3

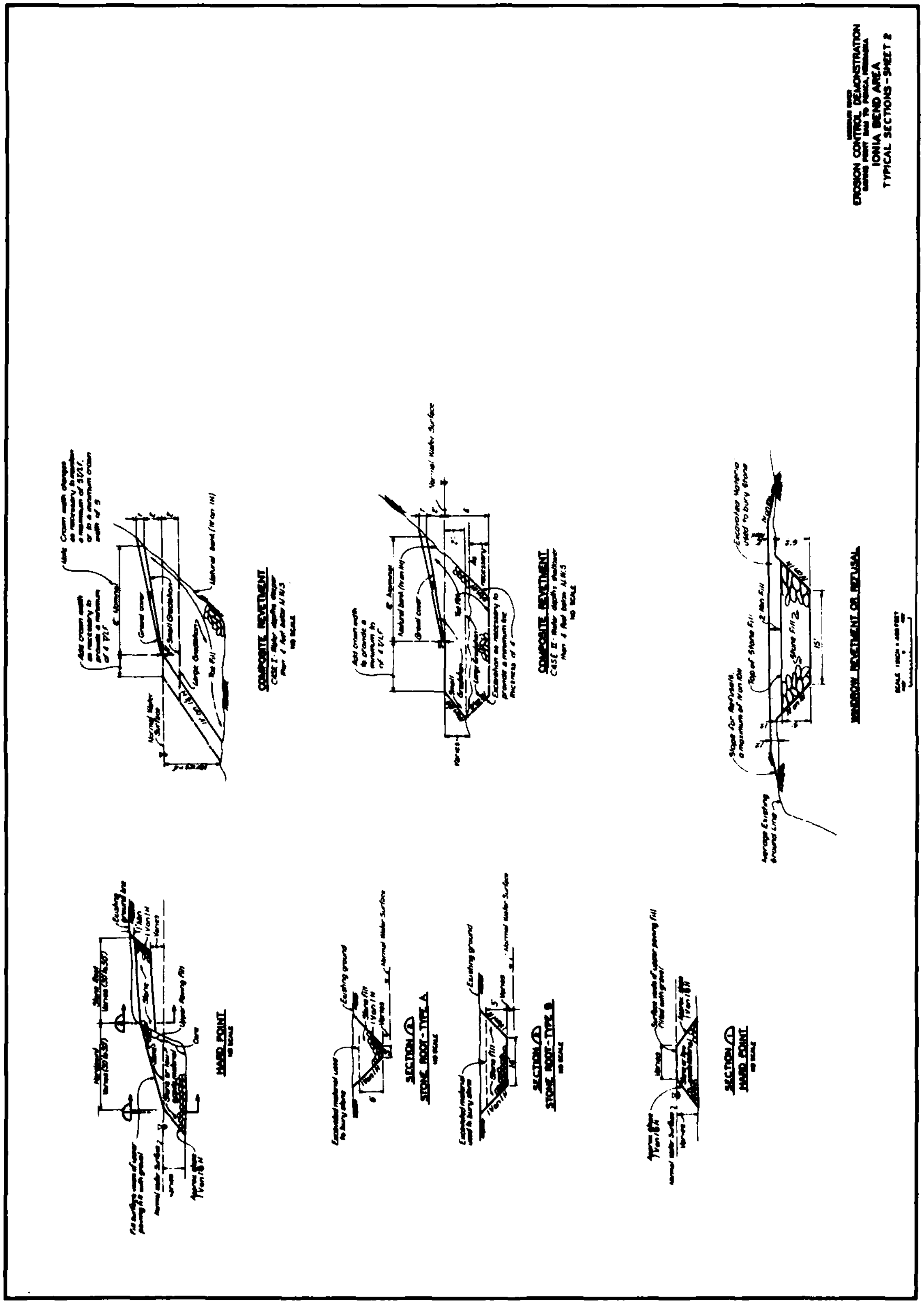

EROSION CONTROL DEMONSTRATION
IONIA BEND AREA
TYPICAL SECTIONS - SHEET 2
COMPOSITE REVETMENT
COMPOSITE REVETMENT
WINDROW REVETMENT OR REFUSAL
HARD POINT
SECTION A
STONE ROOT-TYPE A
SECTION A
STONE ROOT-TYPE B
SECTION A
HARD POINT

PLATE 10-4

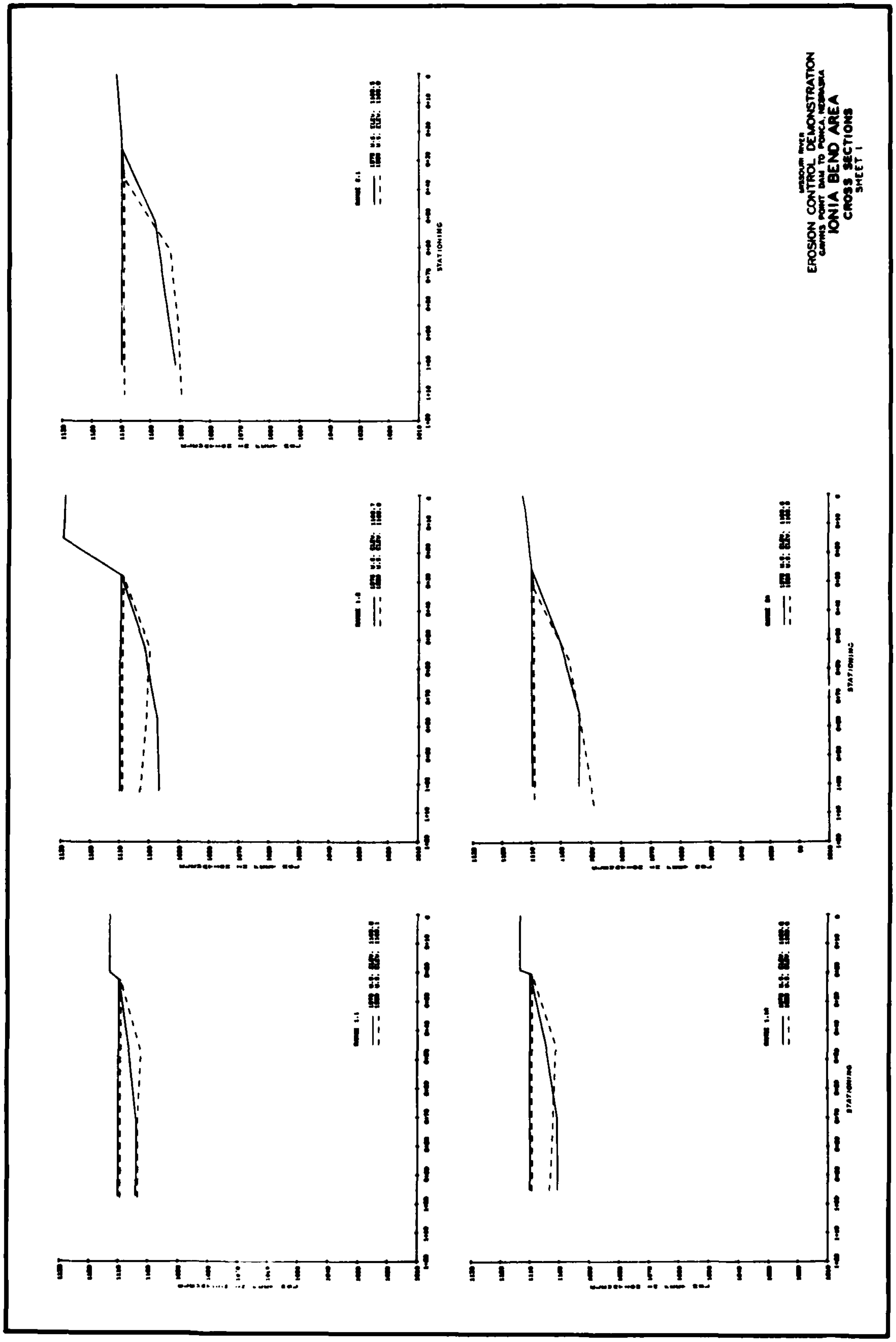

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
IONIA BEND AREA
CROSS SECTIONS
SHEET 1
STATIONING

PLATE 10-5

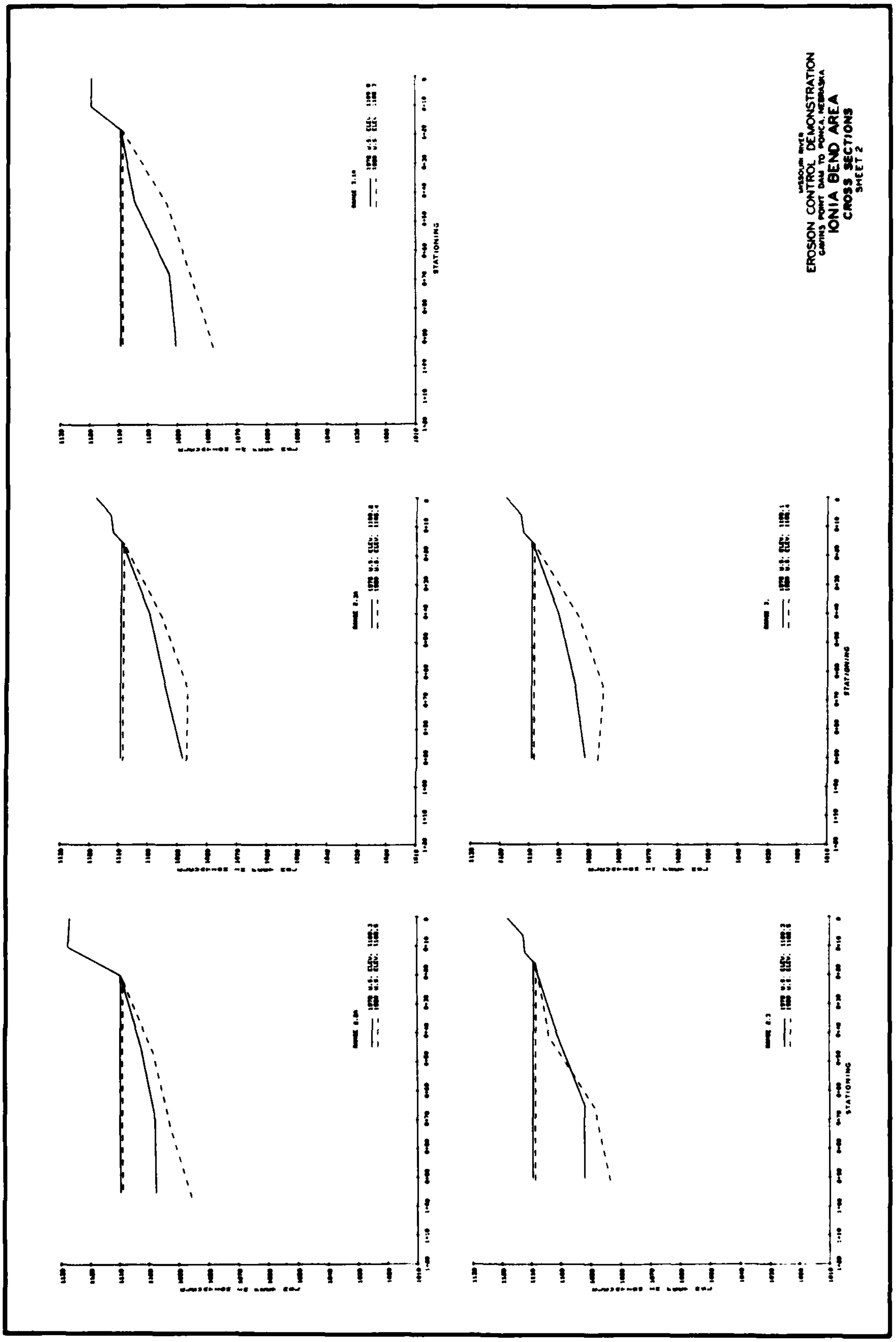

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
IONIA BEND AREA
CROSS SECTIONS
SHEET 2
STATIONING
STATIONING
STATIONING

PLATE 10-6

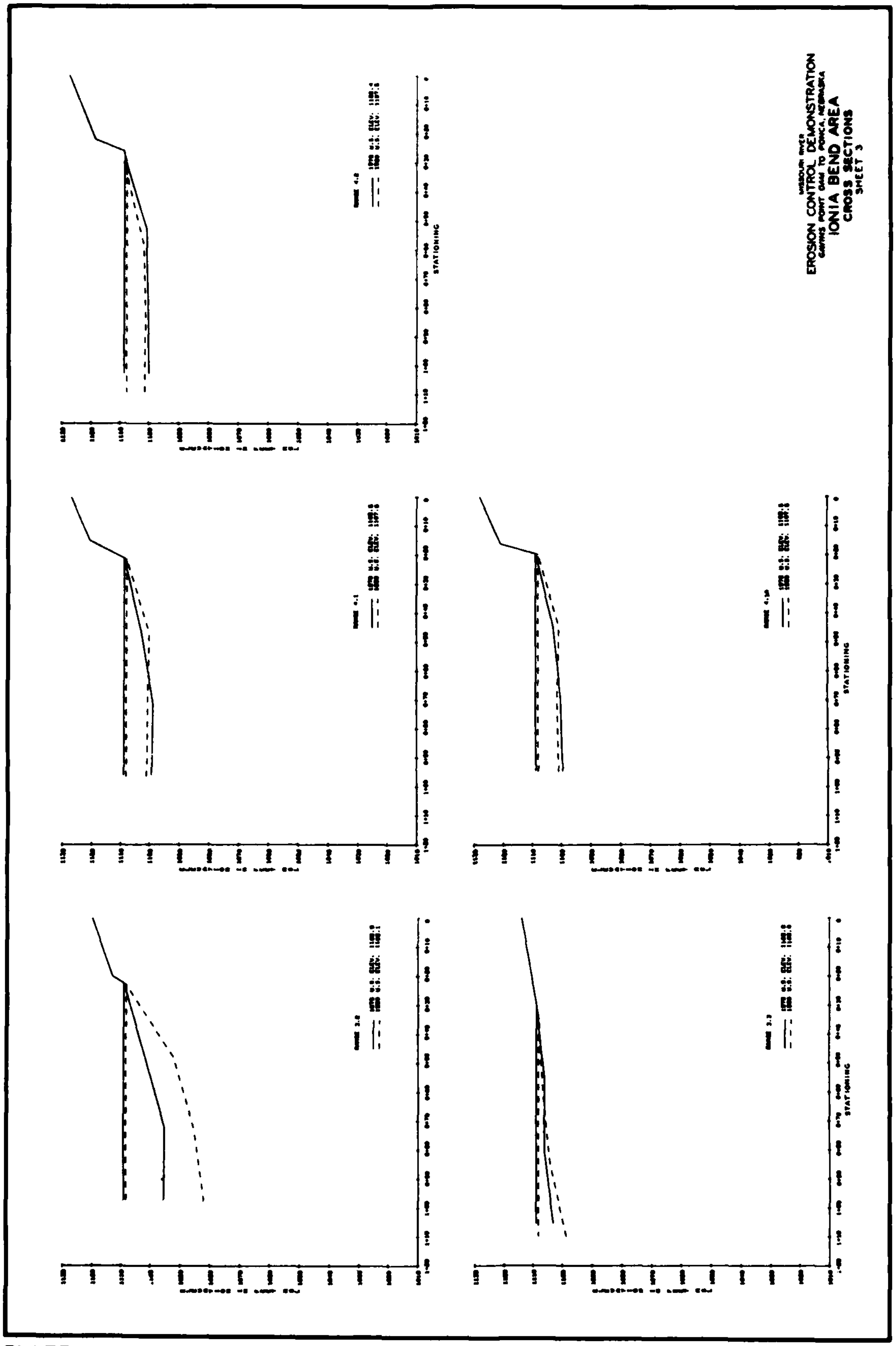

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
IONIA BEND AREA
CROSS SECTIONS
SHEET 3
STATIONING

PLATE 10-7

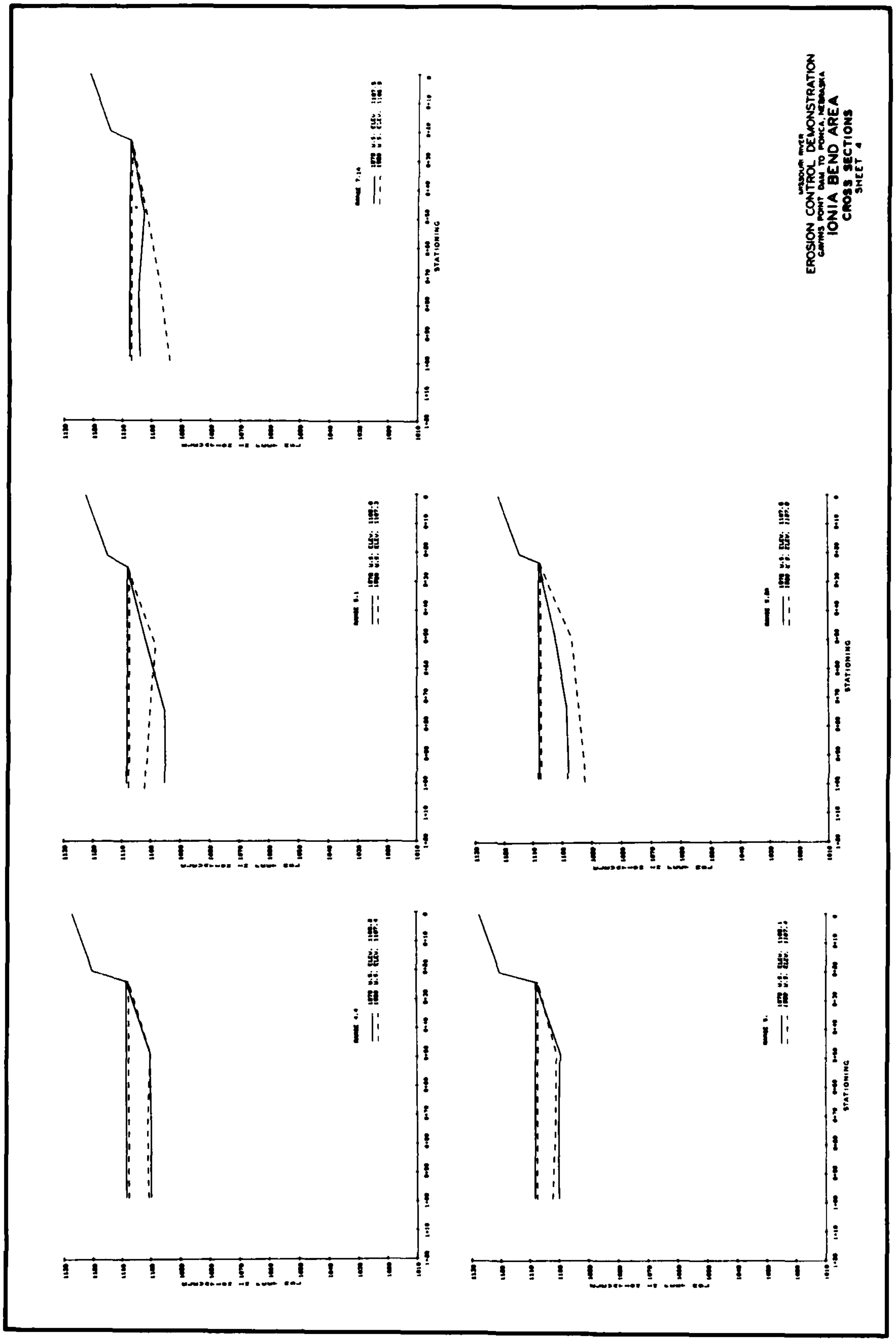

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
IONIA BEND AREA
CROSS SECTIONS
SHEET 4
STATIONING

PLATE 10-8

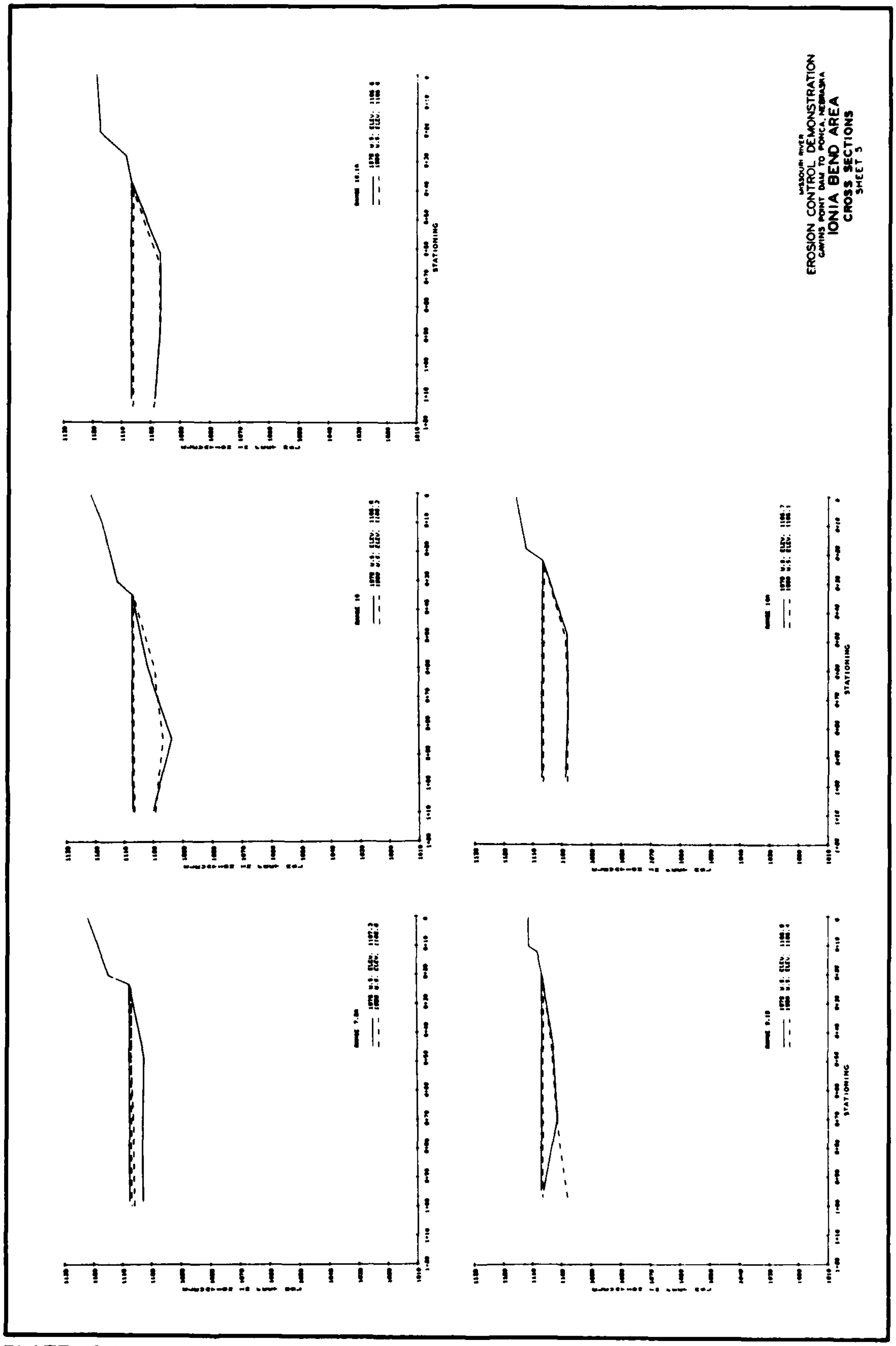

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
IONIA BEND AREA
CROSS SECTIONS
SHEET 5
STATIONING

PLATE 10-9

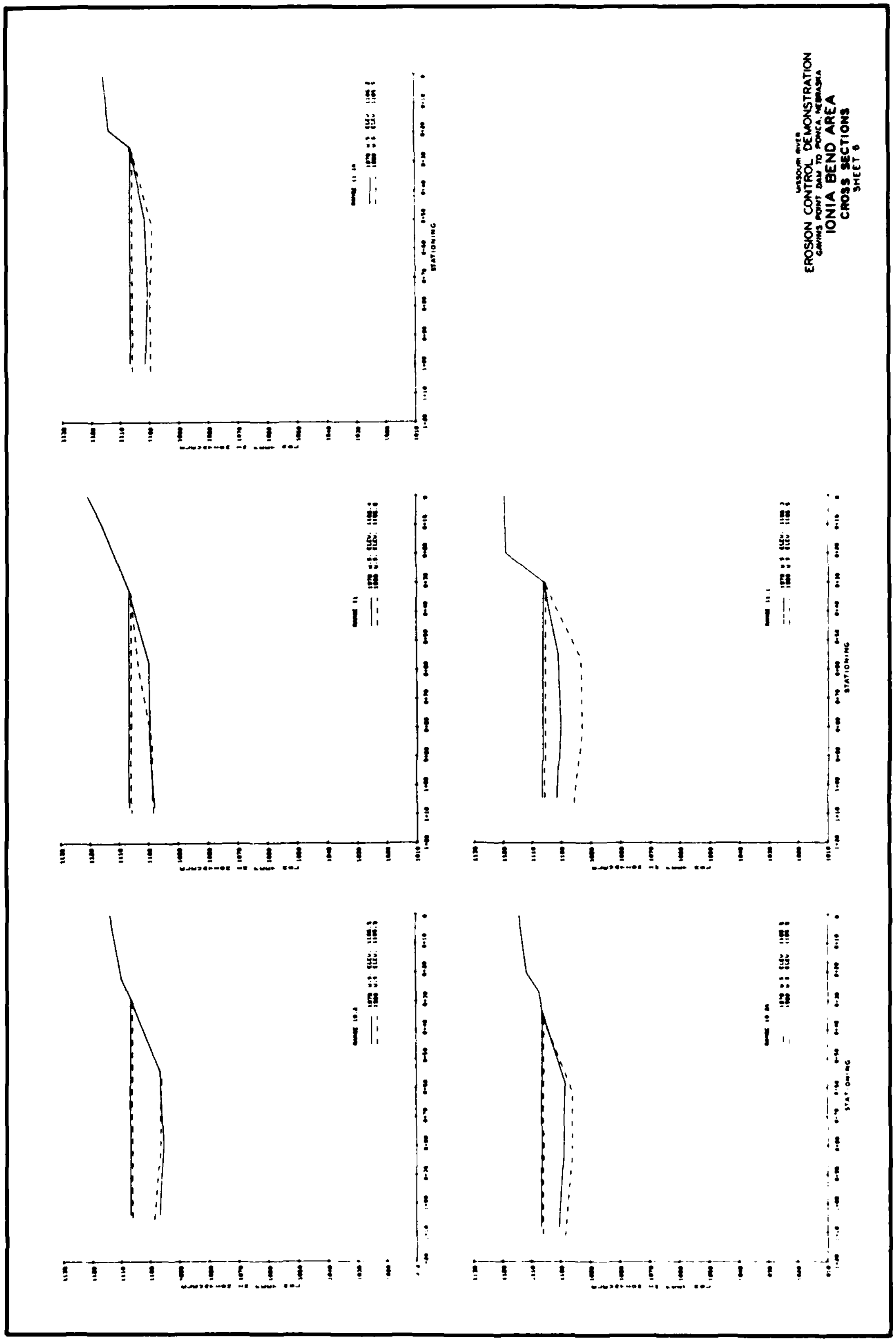
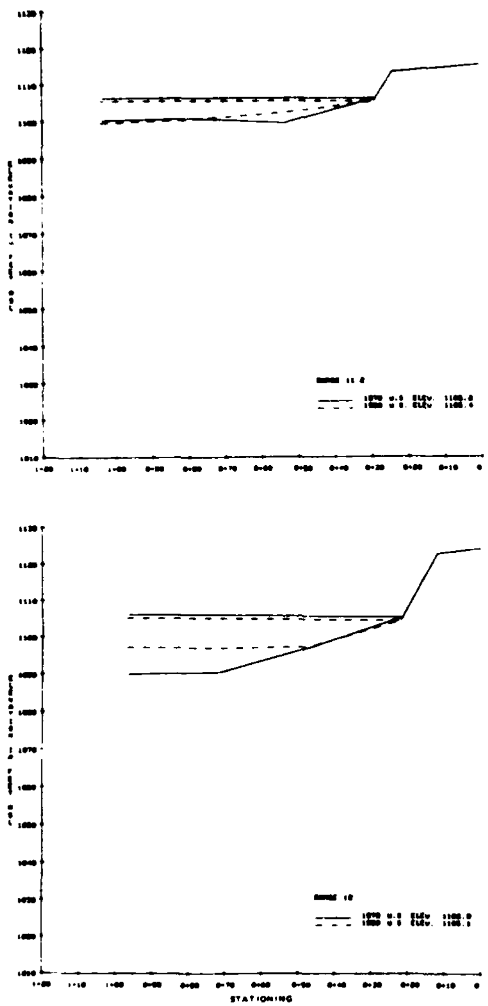

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
IONIA BEND AREA
CROSS SECTIONS
SHEET 6

PLATE 10-10



MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
IONIA BEND AREA
CROSS SECTIONS
SHEET 7

PLATE 10-11

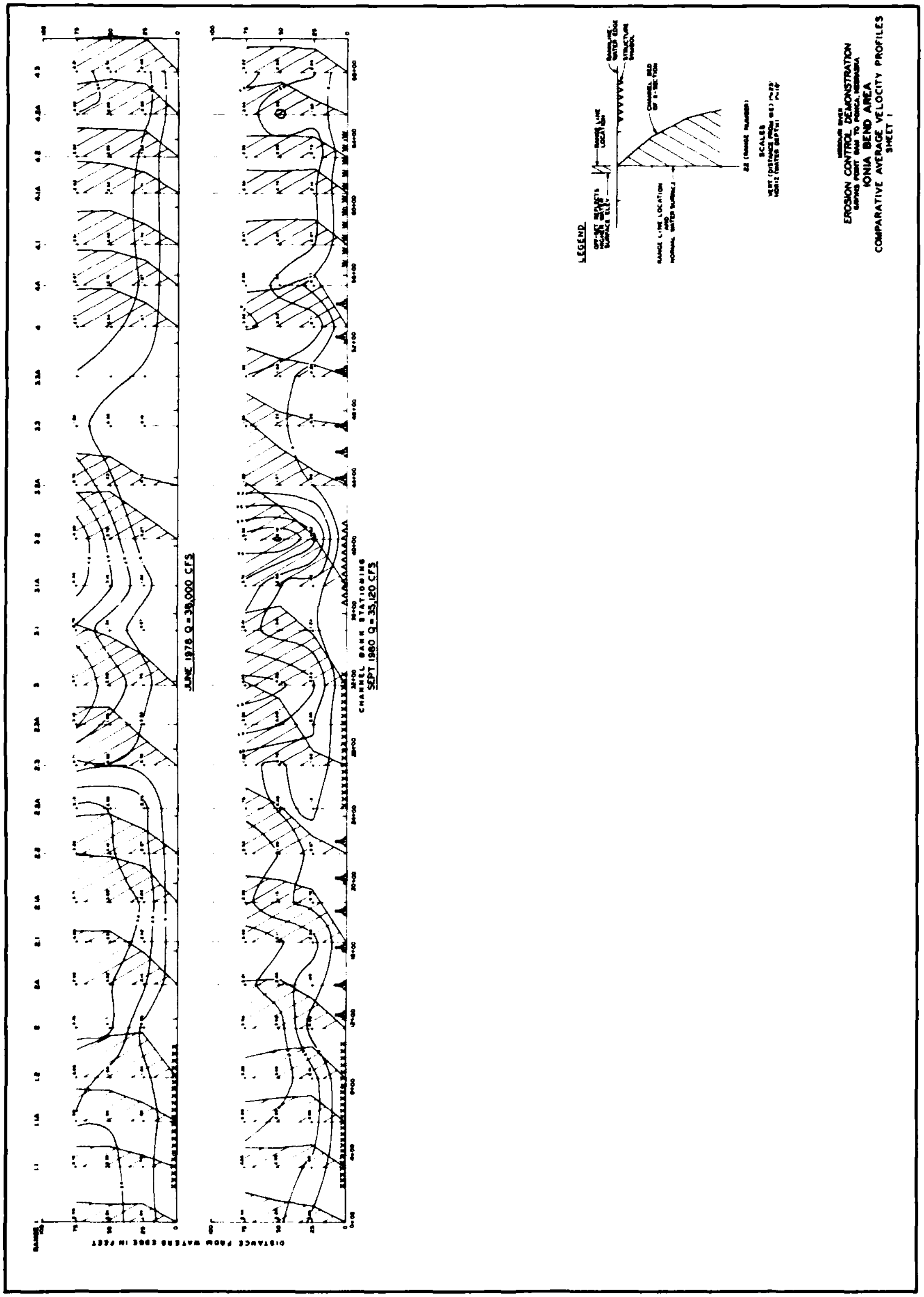

JUNE 1978 Q=38,000 CFS
SEPT 1980 Q=35,120 CFS
CHANNEL BANK STATIONING
DISTANCE FROM WATERS EDGE IN FEET
LEGEND
EROSION CONTROL DEMONSTRATION
IONIA BEND AREA
COMPARATIVE AVERAGE VELOCITY PROFILES
SHEET 1

PLATE 10-12

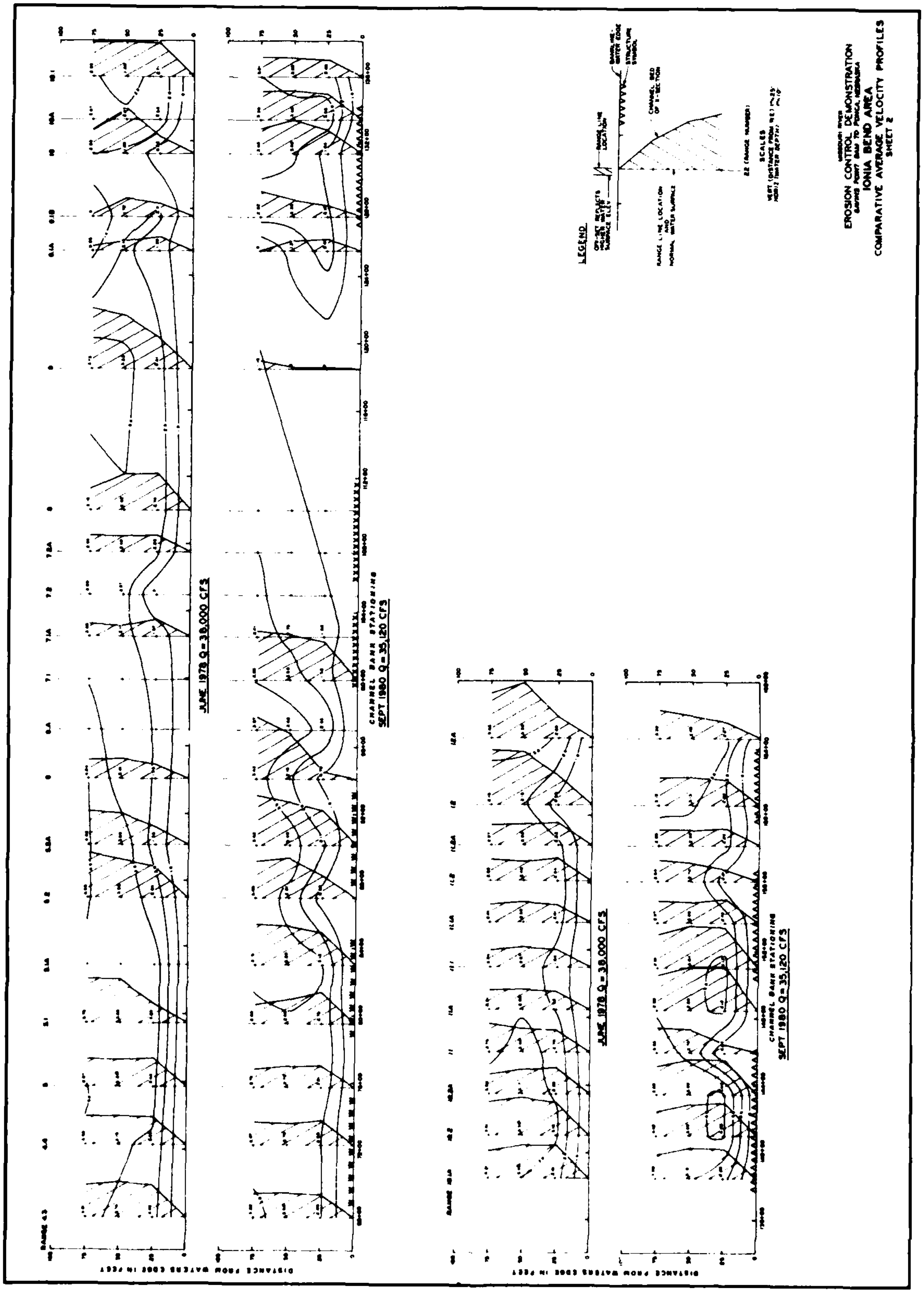

EROSION CONTROL DEMONSTRATION
IONIA BEND AREA
COMPARATIVE AVERAGE VELOCITY PROFILES
SHEET 2
LEGEND
SCALES
JUNE 1978 Q=38,000 CFS
CHANNEL BANK STATIONING
SEPT 1980 Q=35,120 CFS
JUNE 1978 Q=38,000 CFS
CHANNEL BANK STATIONING
SEPT 1980 Q=35,120 CFS

PLATE 10-13

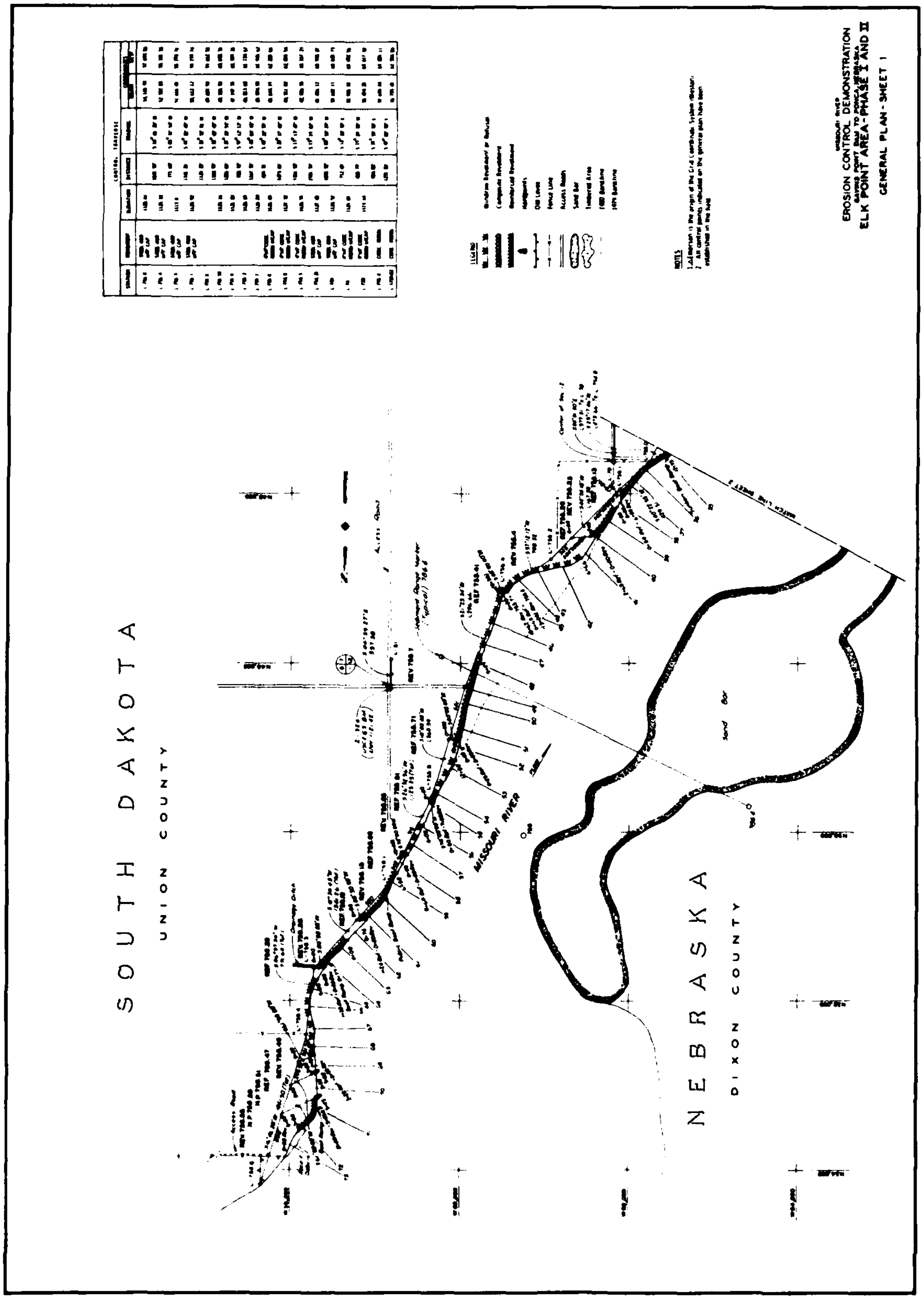

SOUTH DAKOTA
UNION COUNTY
NEBRASKA
DIXON COUNTY
MISSOURI RIVER
Sand Bar
EROSION CONTROL DEMONSTRATION
ELK POINT AREA-PHASE I AND II
GENERAL PLAN-SHEET 1

PLATE 11-1

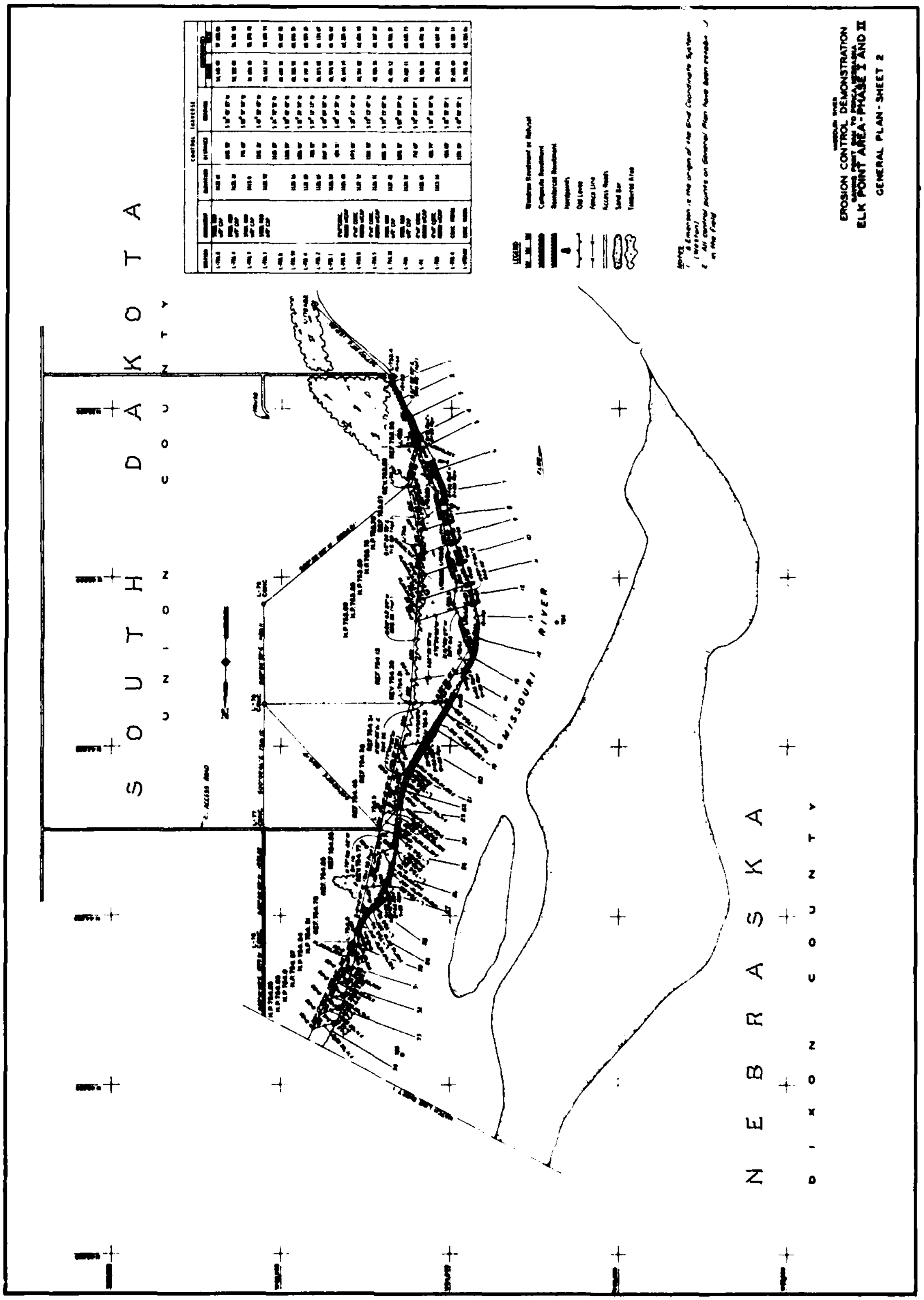
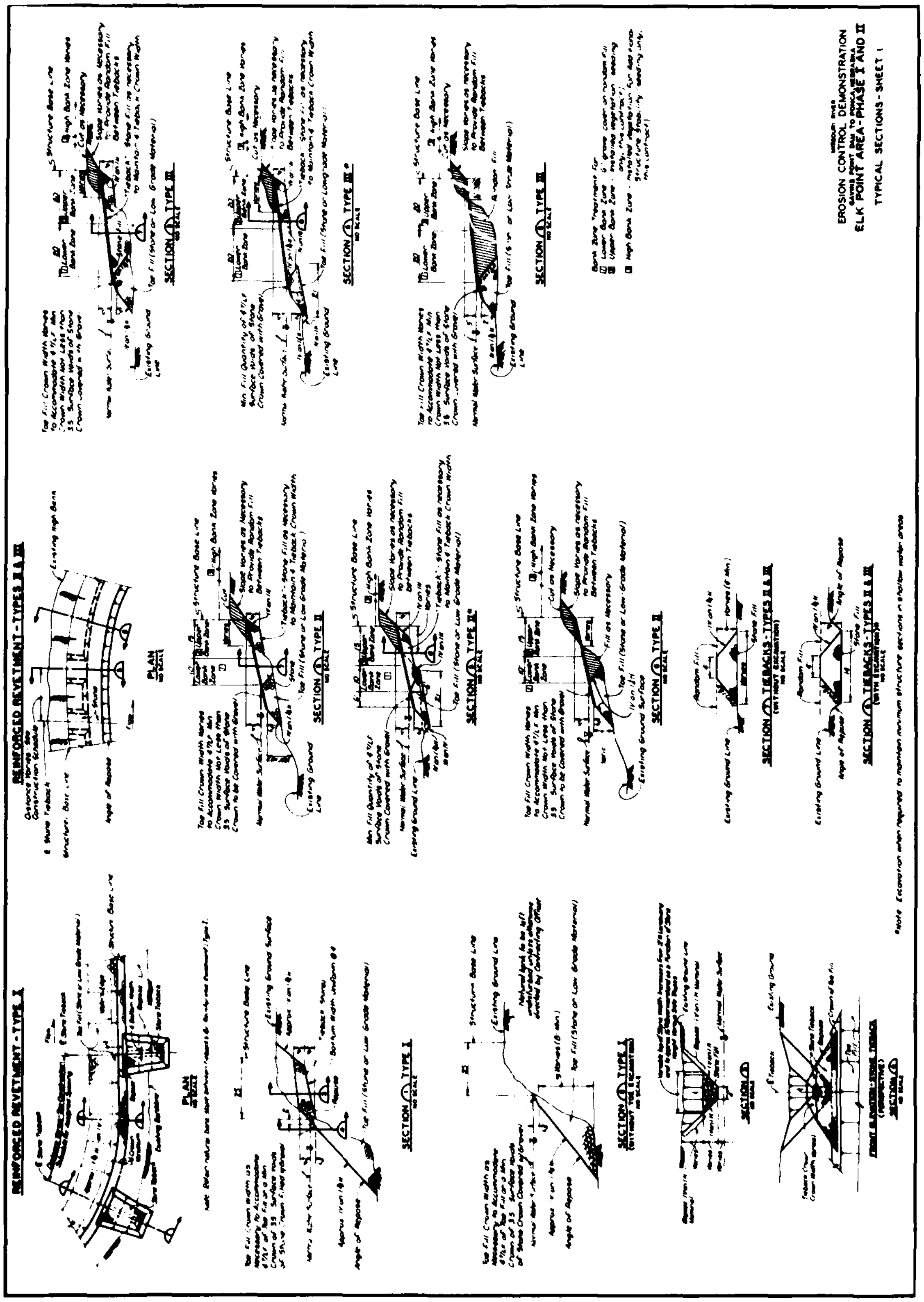
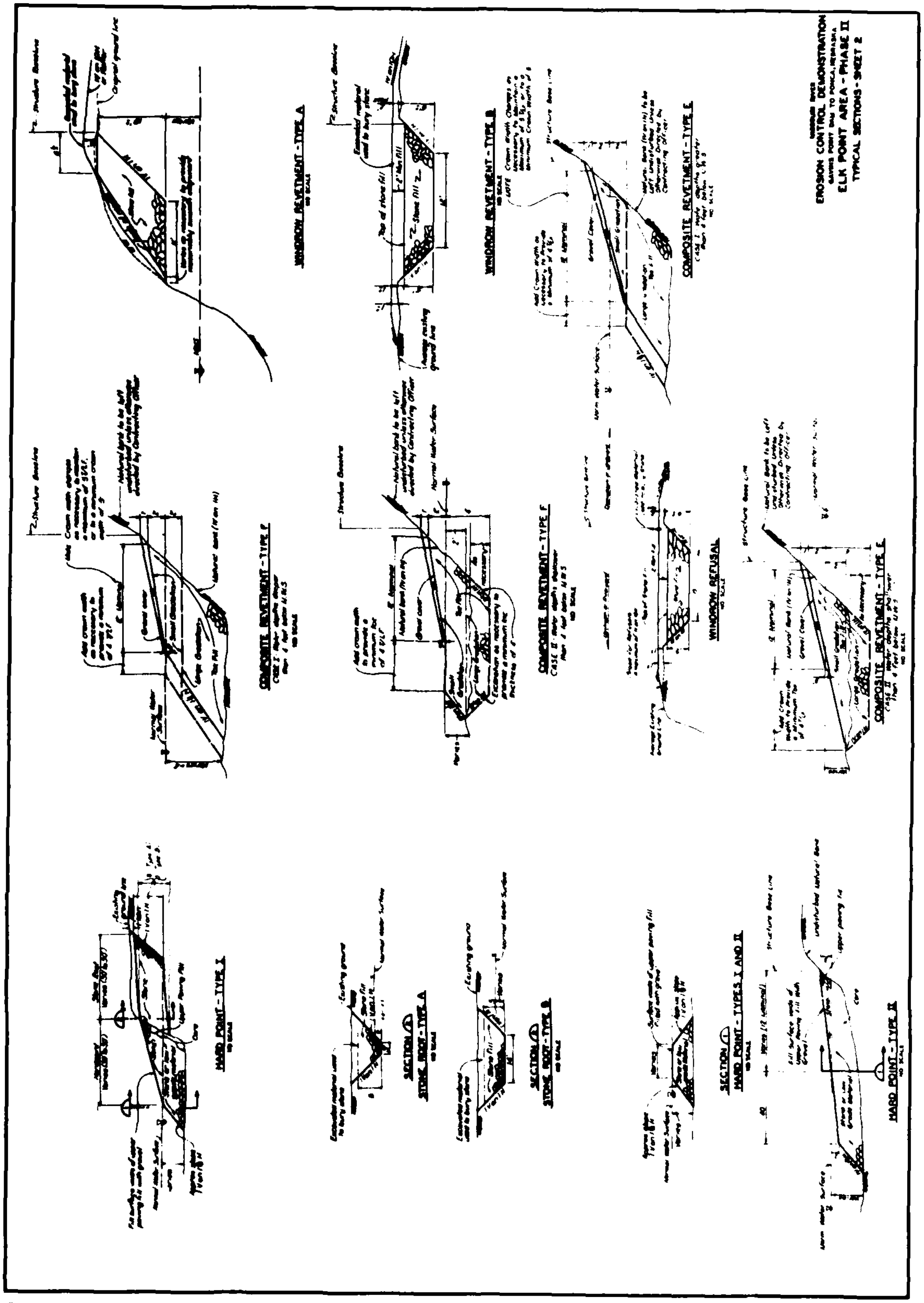

SOUTH DAKOTA
UNION COUNTY
NEBRASKA
DIXON COUNTY
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
ELK POINT AREA - PHASE I AND II
GENERAL PLAN - SHEET 2

PLATE 11-2



REINFORCED REVETMENT - TYPE I
PLAN
NO SCALE
SECTION 1 TYPE I
NO SCALE
SECTION 1 TYPE I
(WITHOUT TOE EXCAVATION)
NO SCALE
SECTION 4
NO SCALE
FRONT ELEVATION - STONE TIEBACK
(PERSPECTIVE)
SECTION 4
NO SCALE
REINFORCED REVETMENT - TYPES II & III
PLAN
NO SCALE
SECTION 2 TYPE II
NO SCALE
SECTION 2 TYPE II*
NO SCALE
SECTION 2 TYPE II
NO SCALE
SECTION 3 TIEBACKS - TYPES II & III
(WITHOUT EXCAVATION)
NO SCALE
SECTION 3 TIEBACKS - TYPES II & III
(WITH EXCAVATION)*
NO SCALE
SECTION 3 TYPE III
NO SCALE
SECTION 3 TYPE III*
NO SCALE
SECTION 3 TYPE III
NO SCALE
*Note: Excavation when required to maintain minimum structure sections in shallow water areas
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
ELK POINT AREA - PHASE I AND II
TYPICAL SECTIONS - SHEET 1

PLATE 11-3



EROSION CONTROL DEMONSTRATION
ELK POINT AREA - PHASE II
TYPICAL SECTIONS - SHEET 2
WINDROW REVETMENT - TYPE A
WINDROW REVETMENT - TYPE B
COMPOSITE REVETMENT - TYPE E
COMPOSITE REVETMENT - TYPE F
WINDROW REFUSAL
HARD POINT - TYPE I
STONE ROOT - TYPE A
STONE ROOT - TYPE B
SECTION
HARD POINT - TYPES I AND II
HARD POINT - TYPE II

PLATE 11-4

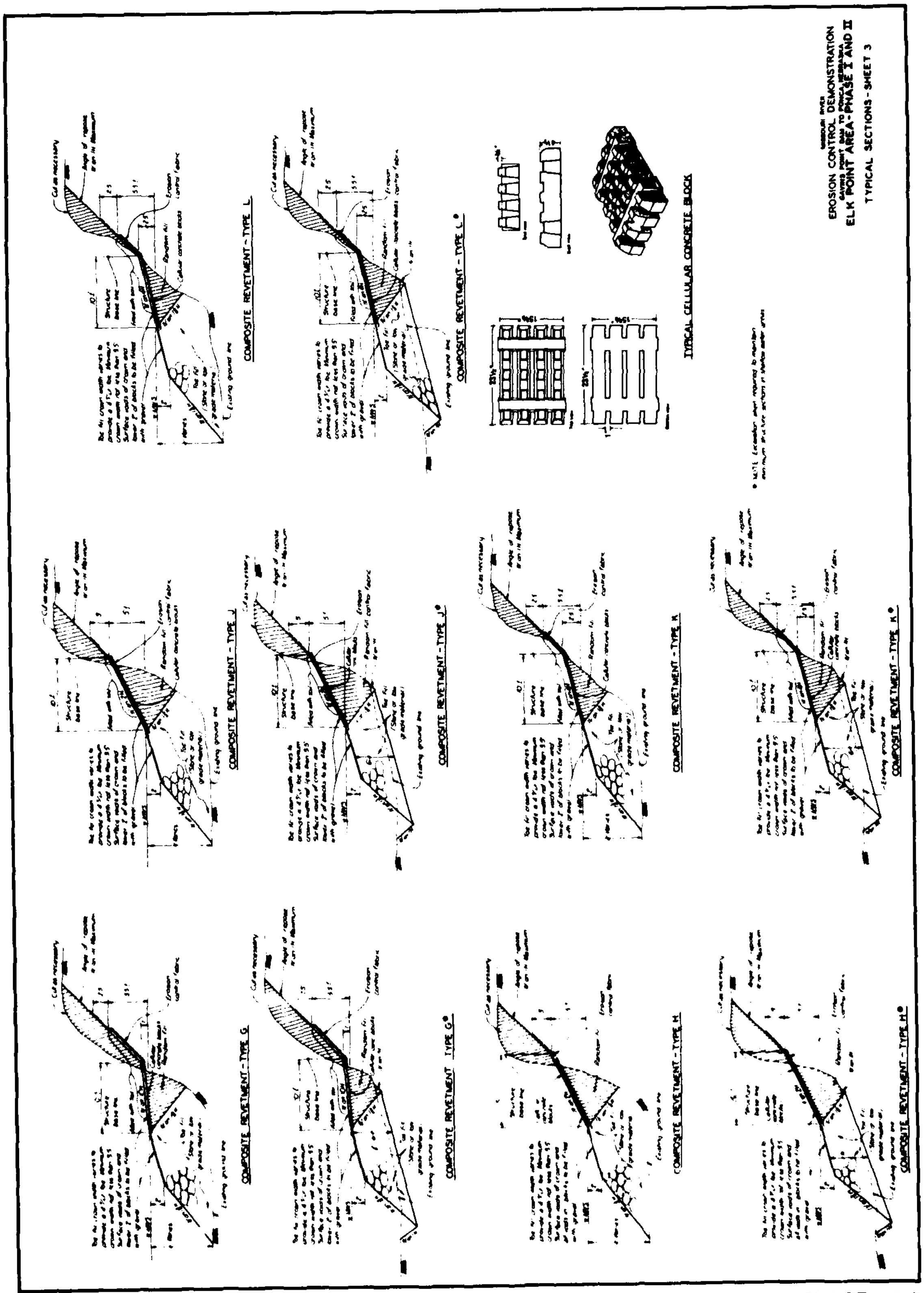

EROSION CONTROL DEMONSTRATION
ELK POINT AREA - PHASE I AND II
TYPICAL SECTIONS - SHEET 3
COMPOSITE REVETMENT - TYPE L
COMPOSITE REVETMENT - TYPE L*
TYPICAL CELLULAR CONCRETE BLOCK
COMPOSITE REVETMENT - TYPE J
COMPOSITE REVETMENT - TYPE J*
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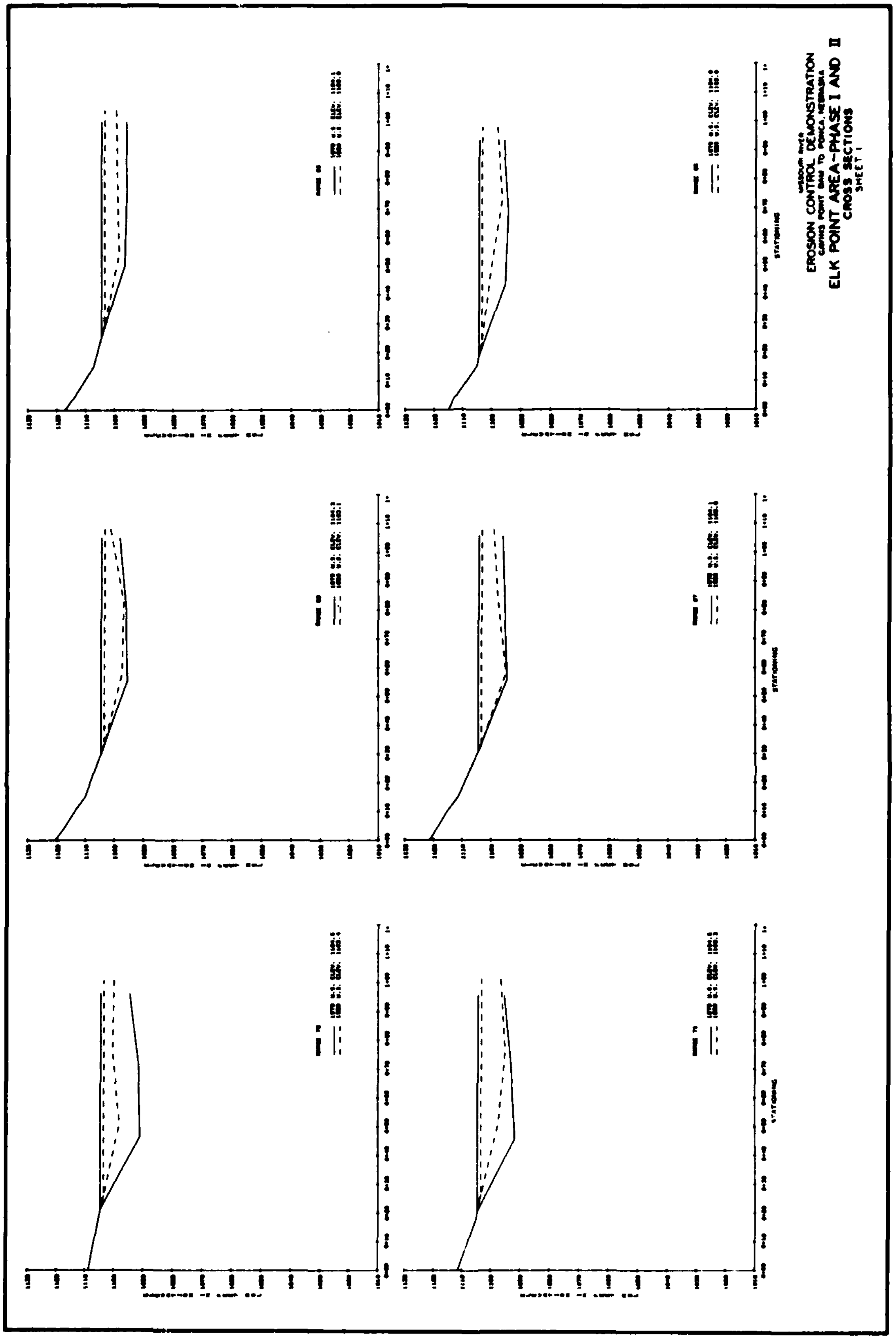
PLATE 11-5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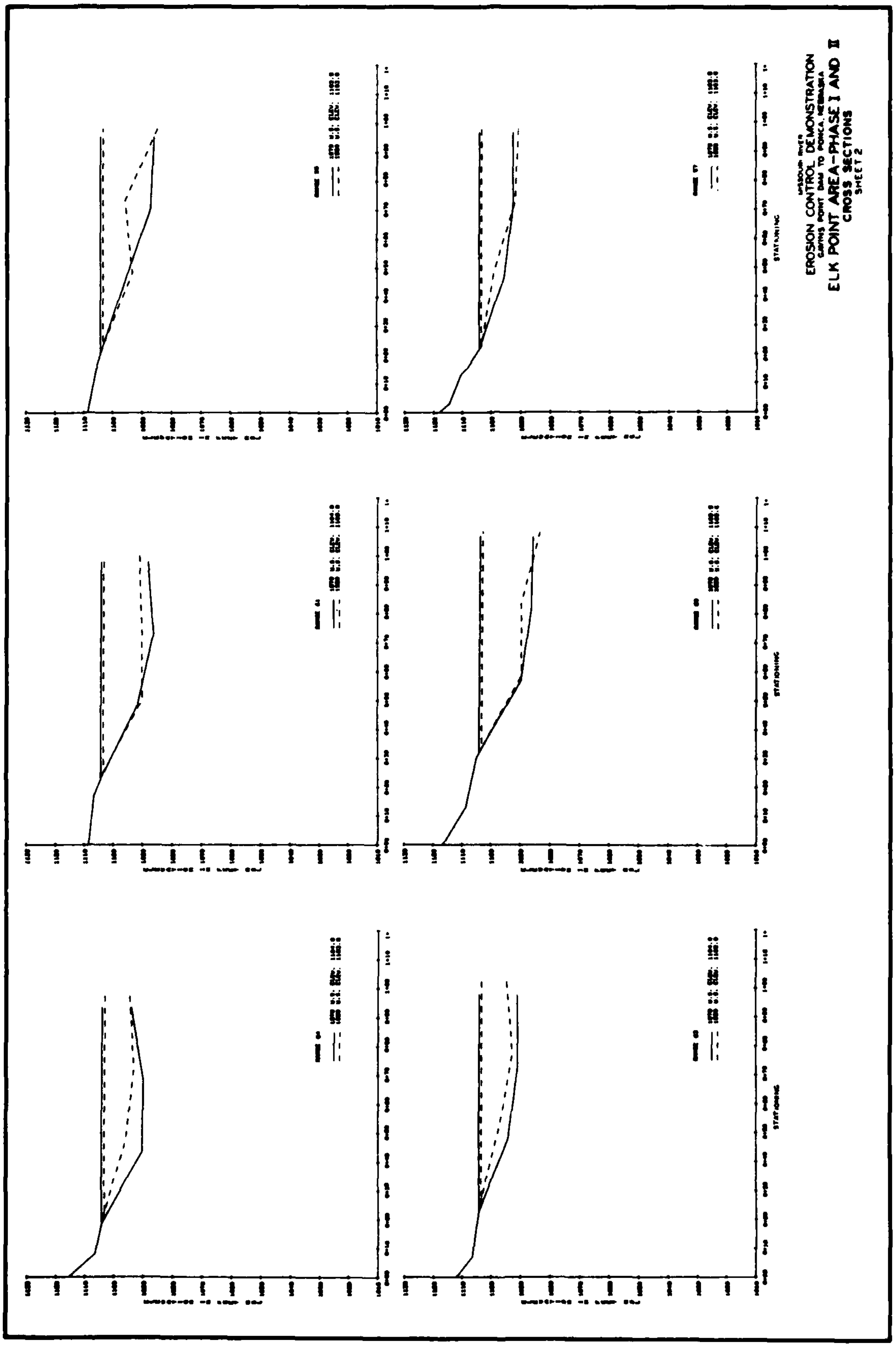
ELK POINT AREA-PHASE I AND II
CROSS SECTIONS

PLATE 11-6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EROSION CONTROL DEMONSTRATION
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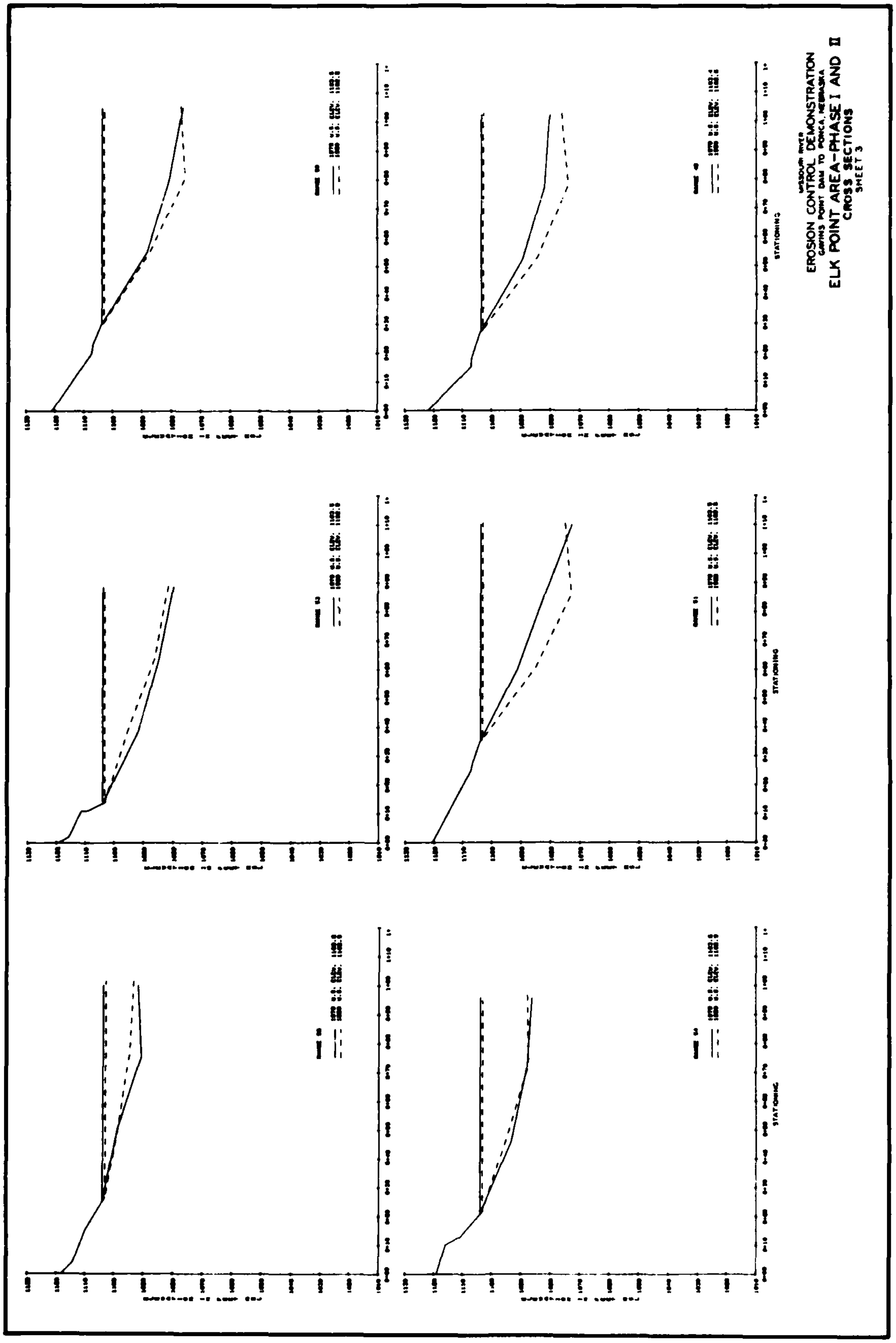
ELK POINT AREA-PHASE I AND II
CROSS SECTIONS
SHEET 2
STATIONING

PLATE 11-7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SHEET 3

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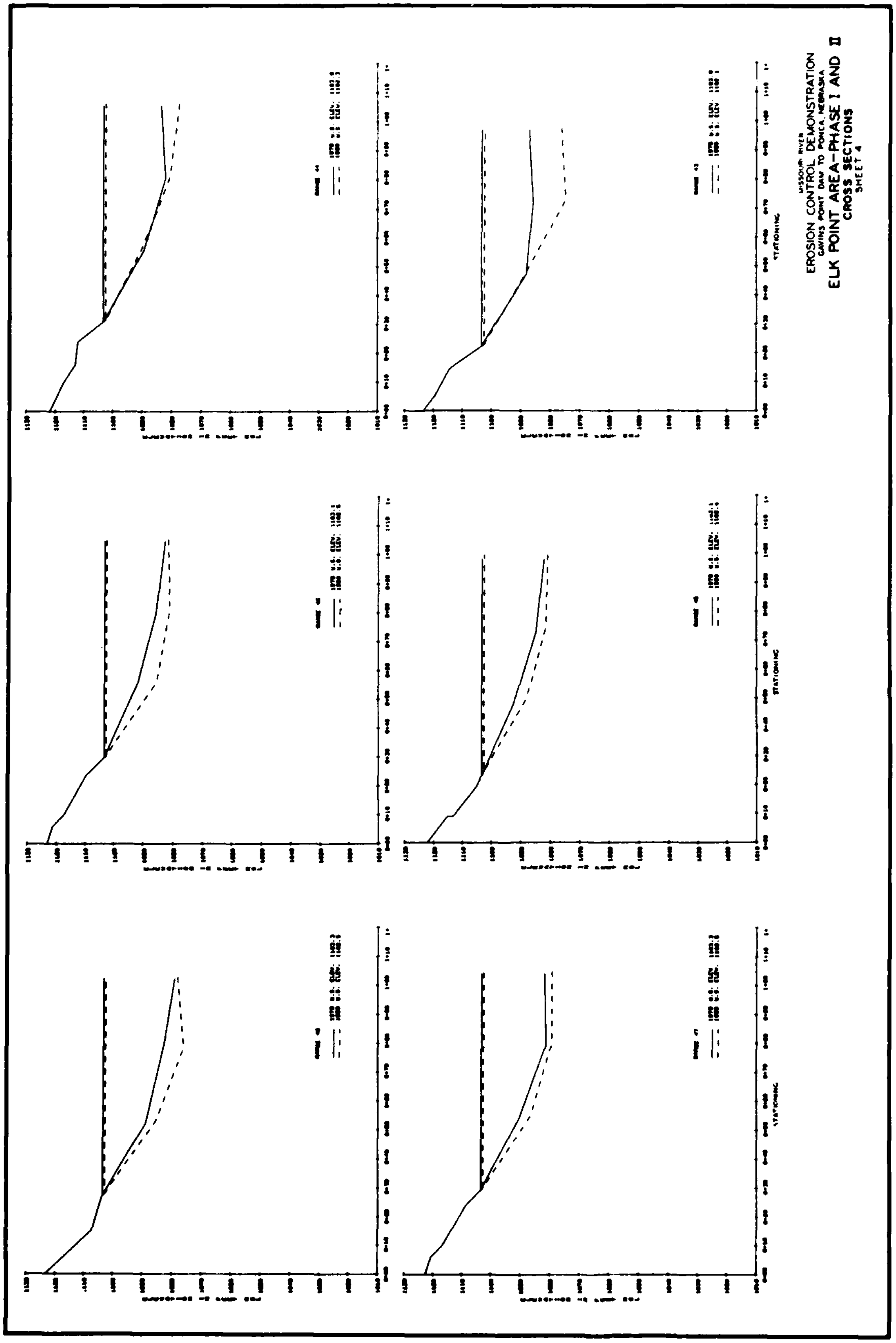
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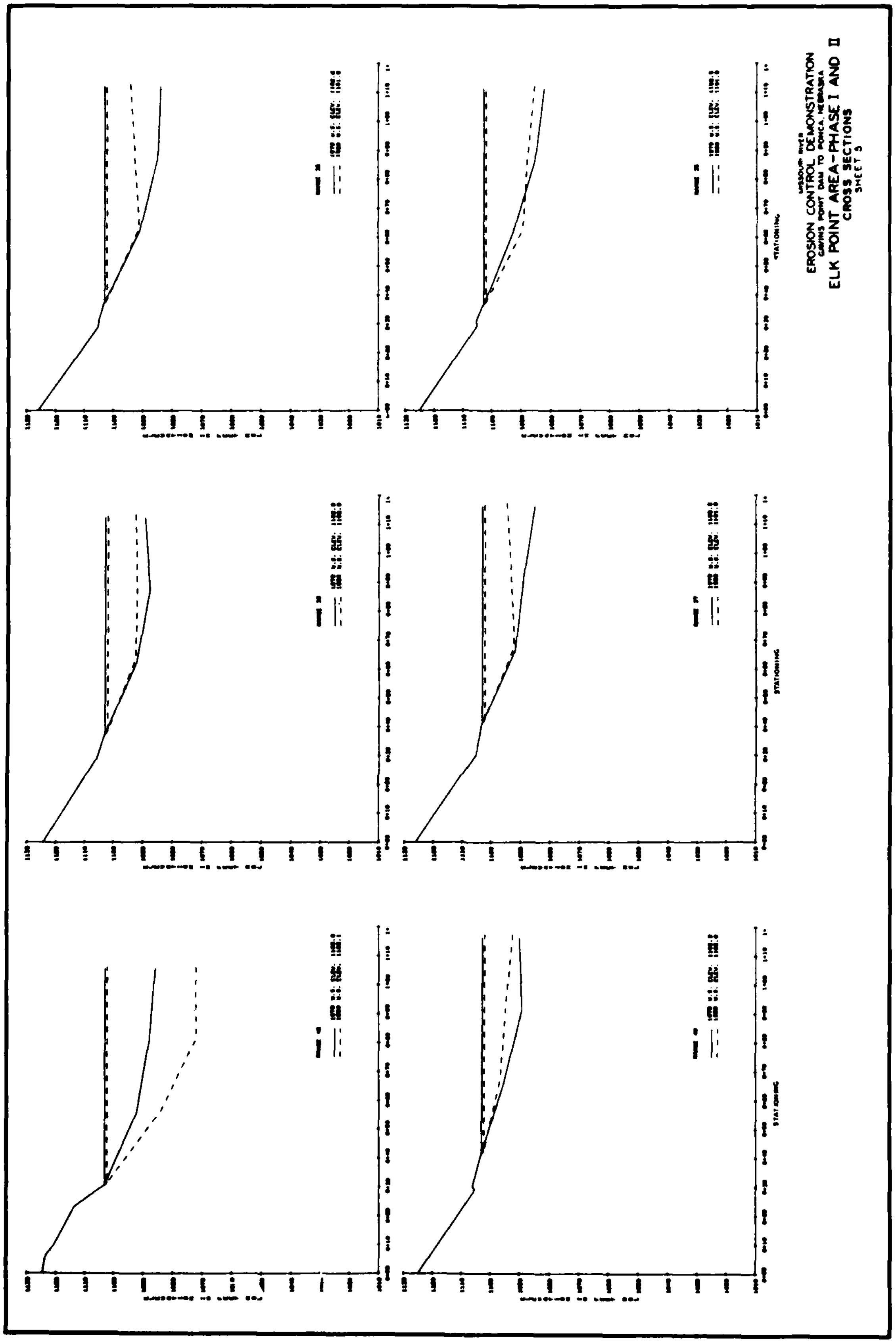
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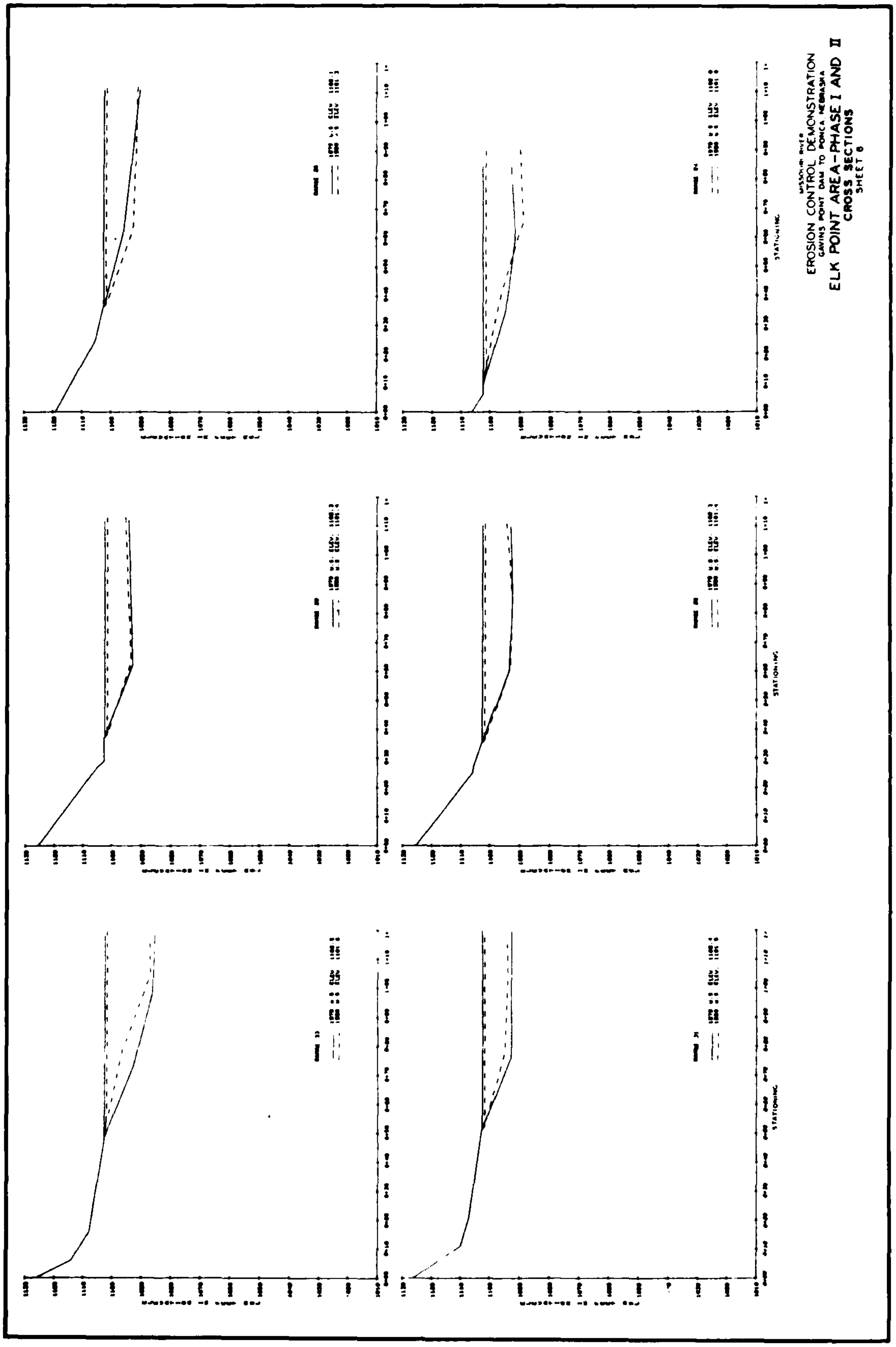
SHEET 5
STATIONING

PLATE 11-10



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GAVINS POINT DAM TO PONCA NEBRASKA
ELK POINT AREA-PHASE I AND II
CROSS SECTIONS
SHEET 6
STATIONING

PLATE 11-11

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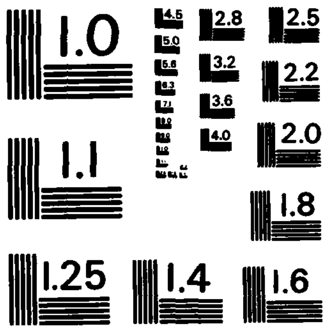
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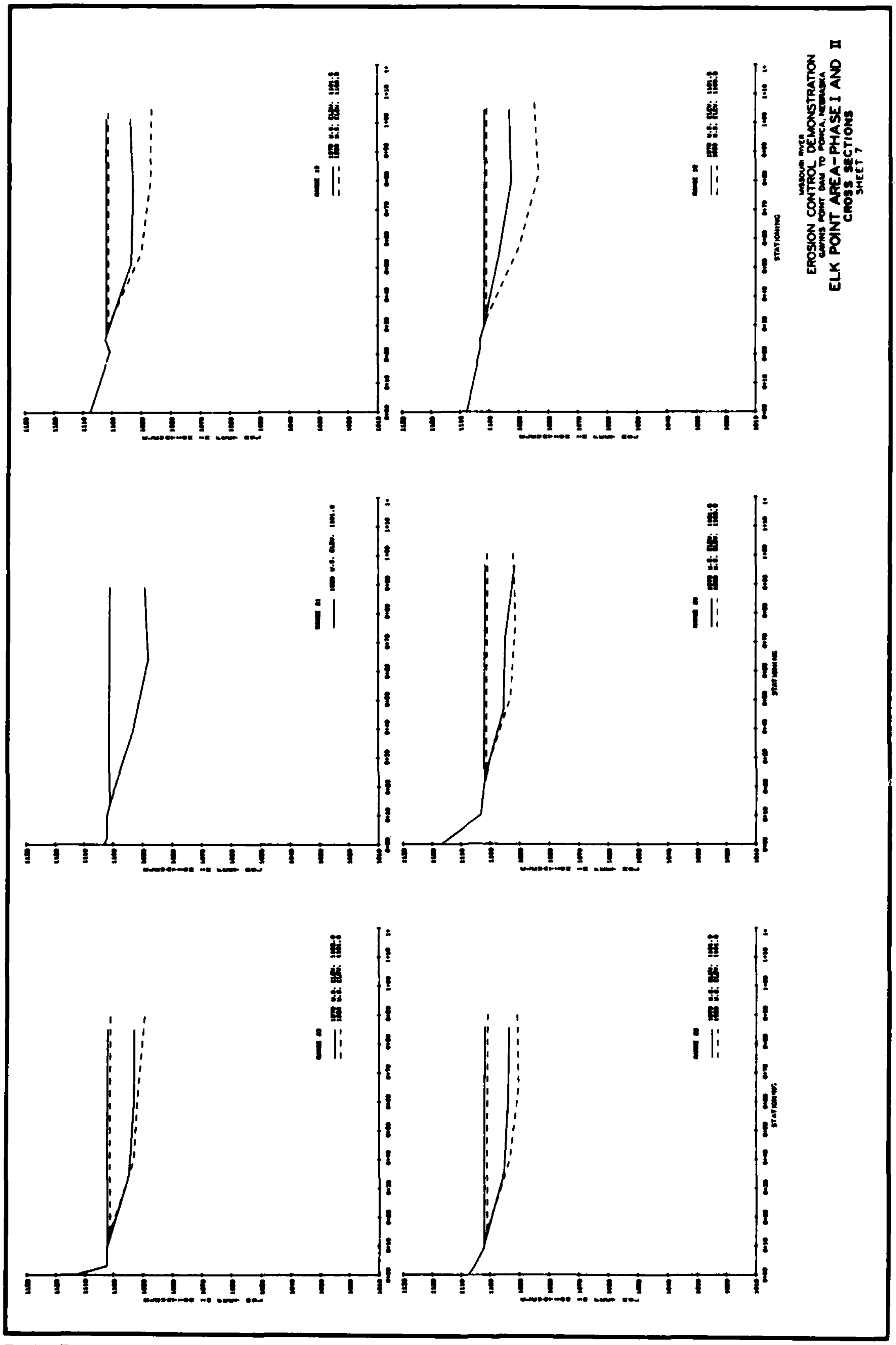
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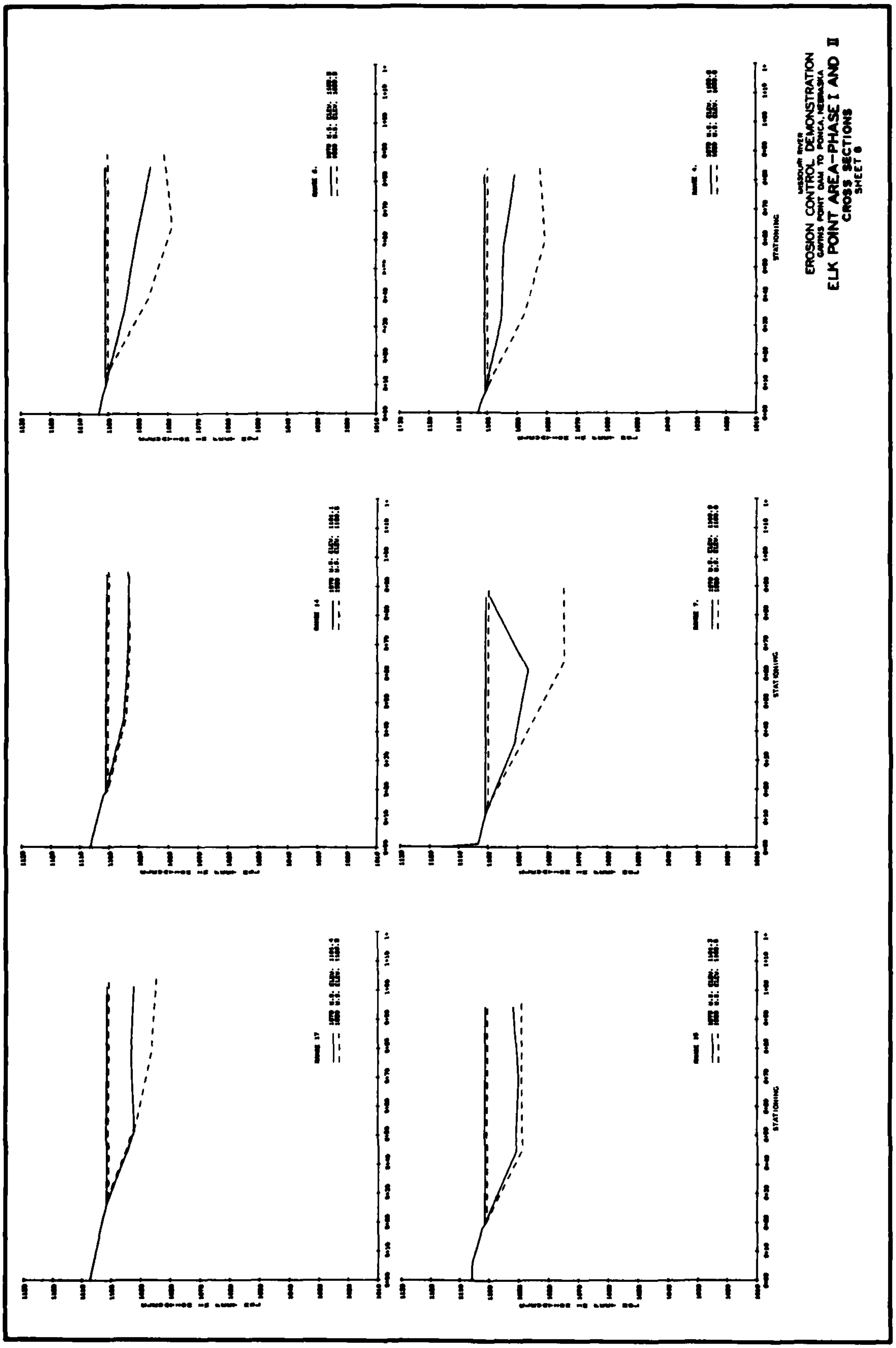
SHEET 7
STATIONING

PLATE 11-12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MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
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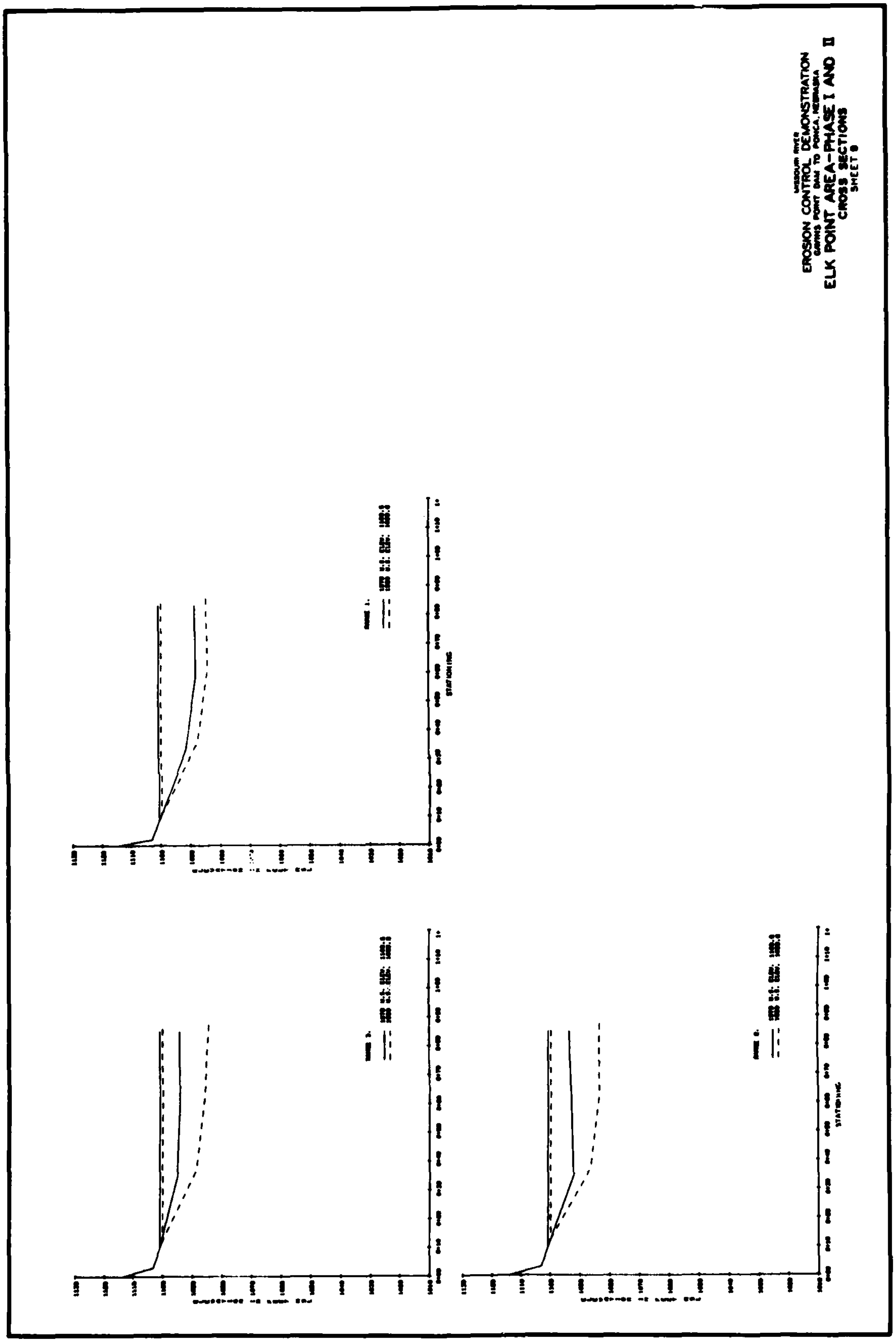
PLATE 11-13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EROSION CONTROL DEMONSTRATION
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ELK POINT AREA-PHASE I AND II
CROSS SECTIONS
SHEET 8
STATIONING

PLATE 11-14

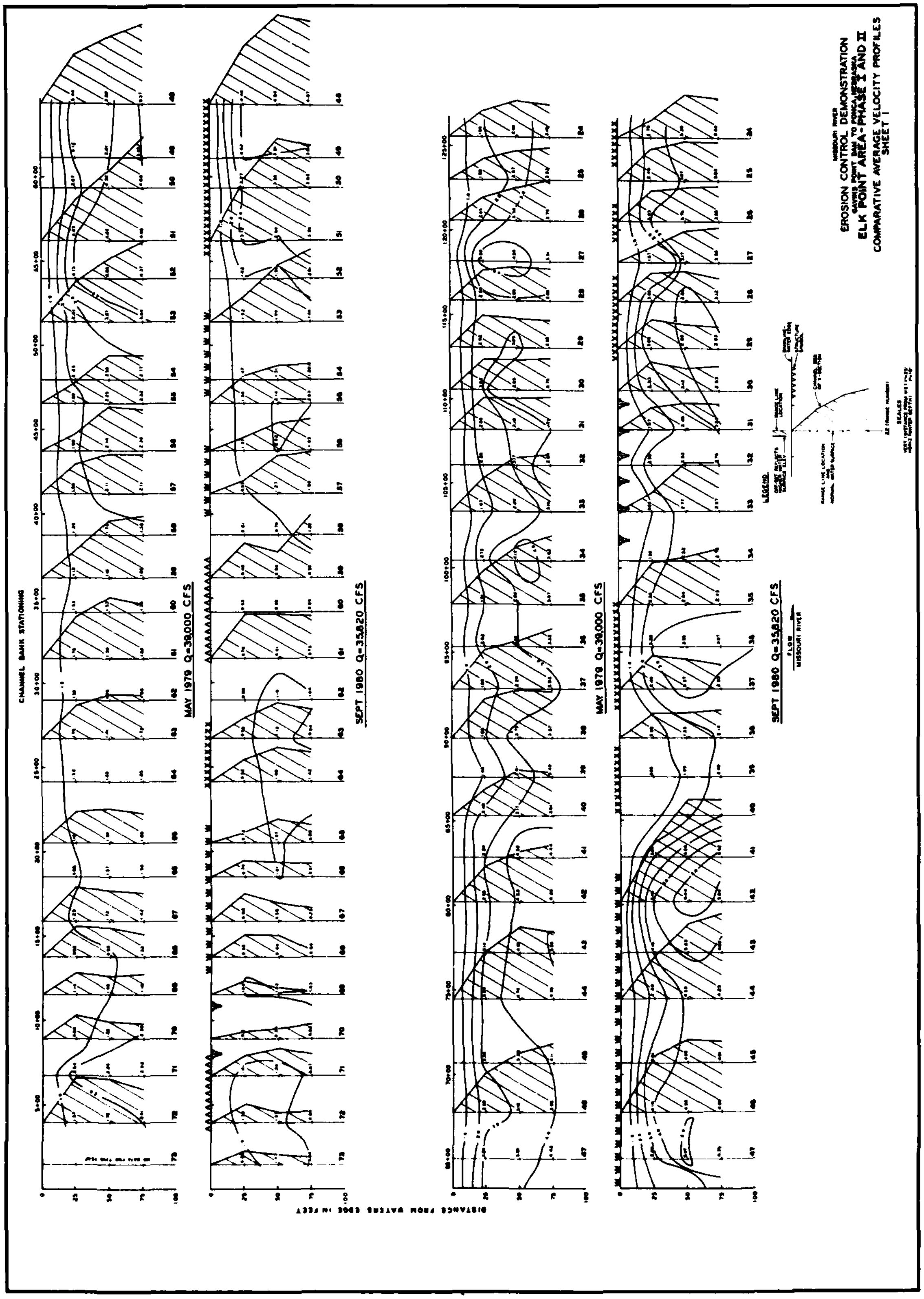
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
ELK POINT AREA PHASE I AND II
COMPARATIVE AVERAGE VELOCITY PROFILES
SHEET I
CHANNEL BANK STATIONING
MAY 1979 Q=39,000 CFS
SEPT 1980 Q=35,820 CFS
LEGEND
DISTANCE FROM WATERS EDGE IN FEET

PLATE 11-15

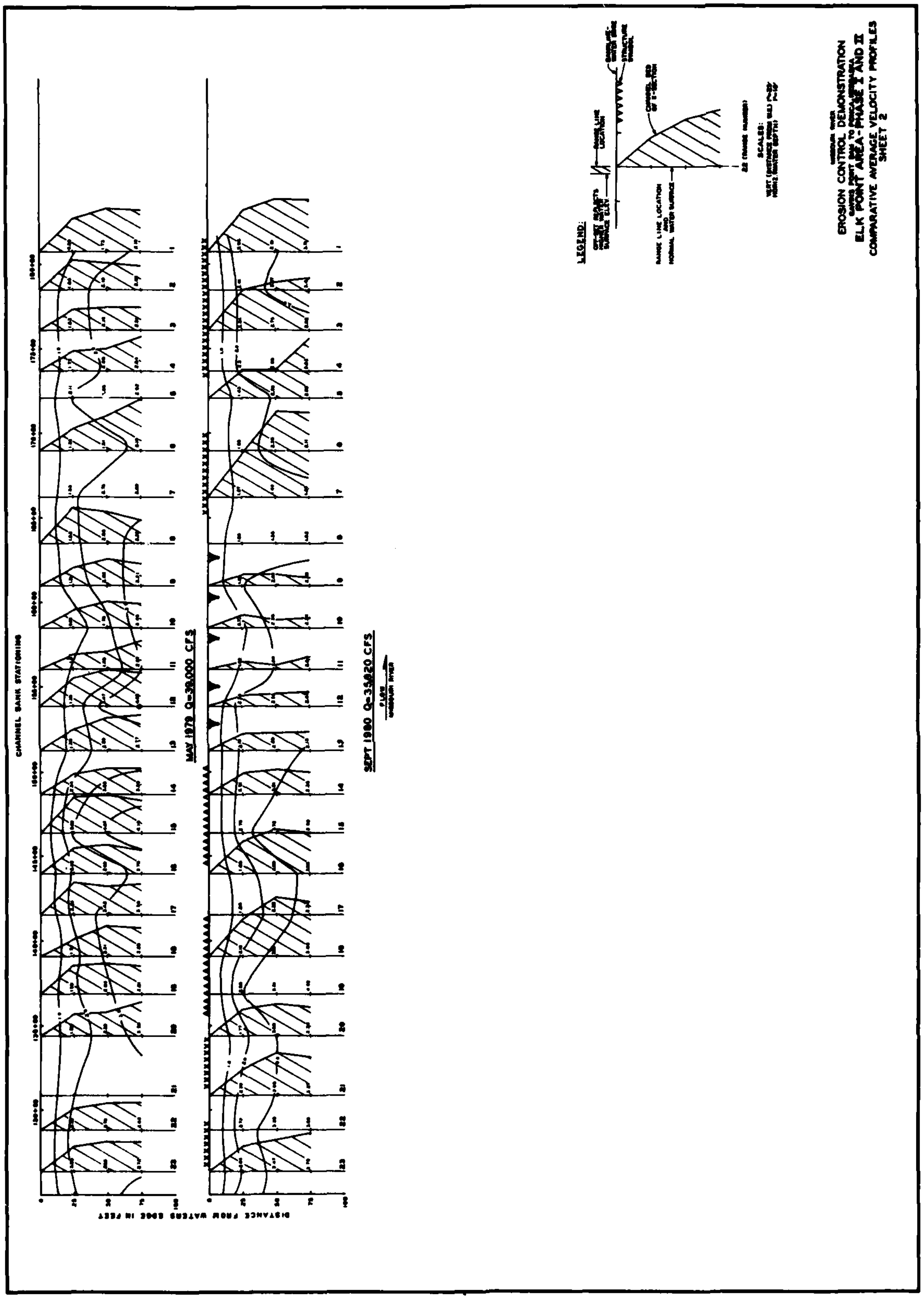
EROSION CONTROL DEMONSTRATION
ELK POINT AREA - PHASE I AND II
COMPARATIVE AVERAGE VELOCITY PROFILES
SHEET 2
LEGEND:
CHANNEL BANK STATIONING
MAY 1979 Q=38,000 CFS
SEPT 1980 Q=35,820 CFS
DISTANCE FROM WATERS EDGE IN FEET

PLATE 11-16

United States Department of the Interior
FISH AND WILDLIFE SERVICE
AREA OFFICE: SOUTH DAKOTA—NEBRASKA—KANSAS
POST OFFICE BOX 250
PIERRE, SOUTH DAKOTA 57501

IN REPLY REFER TO:

June 11, 1981

Colonel Vito D. Stipo
District Engineer
Corps of Engineers, Omaha District
6014 U.S. Post Office & Courthouse
Omaha, Nebraska 68102

Dear Colonel Stipo:

This Fish and Wildlife Service interim report provides an assessment of bank stabilization projects constructed between Fort Randall Dam, South Dakota, and Sioux City, Iowa, under Section 32 of the Water Resources Development Act of 1974. This report was prepared by the Fish and Wildlife Service under the authority and provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et. seq.) to assist the Corps of Engineers in an assessment of the ongoing Demonstration and Evaluation Program.

Please contact us if you have questions concerning the attached report.

Sincerely yours,

C. L. Lowande

for James W. Salyer
Area Manager

Attachment

cc: SDDGFP; Pierre, SD
NE GPC; Lincoln, NE
FWS/ENV; Denver, CO
FWS/ENV; Washington, D.C.

SECTION 32 STREAMBANK EROSION CONTROL DEMONSTRATION PROJECT
SOUTH DAKOTA - NEBRASKA

Interim Fish and Wildlife Coordination Act Report of the U.S. Fish and Wildlife Service on bank stabilization projects implemented within the Missouri River; Fort Randall Dam, South Dakota, to Sioux City, Iowa.

Approved:

6/12/81
Date

C. L. Fowards
ACTING Area Manager
South Dakota - Nebraska - Kansas

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Preface

The present project is authorized by the Streambank Erosion Control Evaluation and Demonstration Act of 1974 (Section 32 of the Water Resources Development Act of 1974). The legislation specifically authorized, in addition to numerous studies, the construction of erosion control demonstrations at multiple sites on the Missouri River. At this time, ten bank stabilization projects have been completed or are being constructed in the two free-flowing reaches of the Missouri River within South Dakota and Nebraska. The Final Environmental Impact Statement for this segment of the Section 32 Program was circulated on May 5, 1980.

This report supplements an earlier report on fish and wildlife aspects of the Section 32 Program issued by the Fish and Wildlife Service on May 26, 1978. This report has been prepared under authority of the Fish and Wildlife Coordination Act, 16 U.S.C. 661 et. seq., and is an interim report, as requested in the 1981 Scope of Work for this project. This report has been coordinated with the South Dakota Department of Game, Fish and Parks and the Nebraska Game and Parks Commission and incorporates the findings and recommendations of a number of site-specific evaluations prepared by this Service.

Data and findings from independent studies of fish and wildlife for the North Dakota portion of the Section 32 Program are not included.

Location and Setting

The project, or projects (individual segments), are on the middle Missouri River below Fort Randall Dam, South Dakota, and below Gavins Point Dam, South Dakota and Nebraska. The dams are two of six major dams built under the Pick-Sloan program, a marriage of proposals put forth by the Army Corps of Engineers and the Bureau of Reclamation to explore and develop the Missouri River Basin's power, irrigation, flood damage prevention, and navigation potential. Fort Randall Dam was begun under the joint plan in 1946. Power generation units were in operation by 1956. The lower-most of the six main-stem dams, Gavins Point near Yankton, South Dakota, was begun in 1952 and created the 25-mile long Lewis and Clark Lake. To maintain full service to navigation, Gavins Point Dam releases sufficient water to meet target flows of 31,000 cubic feet per second (CFS) at Sioux City.

Below Fort Randall Dam, the Missouri River flows in a narrow floodplain between steep bluffs until it reaches the upper end of Lewis and Clark Lake, 36.3 miles downstream. This reach of the Missouri River is one of the few reaches of the river which remains in a relatively natural state. The valley of the Missouri River downstream from Fort Randall Dam averages about 1.4 miles in width between high chalk bluffs. Within this narrow valley, the high-flow channel of the river alternately parallels one bluff for one or two miles and then crosses over to meet the opposite bluff. The high-flow channel occupies about 32 percent of the land area between the bluffs. The area between the high banks is occupied by the river channel, sandbars, and islands.

As a result of ongoing erosion and bar building processes, braided, sinuous channels twist among sheltered backwaters, sloughs, chutes, gravel bars, sandbars, mud flats, snags, alluvial islands, deep pools, marshland, and shallow water areas. The constant process of erosion and deposition forms a transitory or seral stage of vegetative communities that are of critical importance to numerous wildlife species.

The area below Fort Randall Dam was cover typed using 1974 aerial photographs. The habitat types defined by Clapp (1976), in his study of wildlife habitats along the unchannelized Missouri River in South Dakota, were identified and measured along this river reach. The area below the dam, including all the land and water between the base of the bluffs, contained 31,541 acres, which in 1974 consisted of 21,284 acres of land and 10,257 acres under-the-water classification. Low sandbars and cattail marsh acreages were included in the water area.

Of the land area, 15,284 acres (71.8 percent) were farmed. The types considered as wildlife habitat are cottonwood-dogwood, willow-cottonwood, cattail marsh, and sand dunes. Total acreage of these habitats was 6,432 acres. Willow-cottonwood and cattail marsh comprised 14 and 12 percent of the area respectively.

The 58-mile segment of the Missouri River from Gavins Point Dam, South Dakota, to Ponca State Park in Nebraska is one of the few reaches of this river free of man-made structures. This reach offers an example of a free-flowing river in a relatively natural state. This river reach has also been designated as a National Recreational River because of the natural and cultural values Congress deemed worthy of preservation. This reach is characterized by a wide, meandering channel which contains numerous shifting sandbars and subsidiary channels. The channel width ranges from 1,000 to 5,000 feet with the average width being 2,500 feet. Depths range up to 26 feet but average less than 6.5 feet. The stream gradient is approximately 1 foot per mile. The bottom consists primarily of sand except in backwater and marsh areas where silt deposits occur. Releases from Gavins Point Dam from mid-March to mid-November average over 32,000 $feet^3$/second, while during the remainder of the year they are normally less than 20,000 $feet^3$/second.

In this reach, Kallemeyn and Novotny (1977) described seven aquatic habitats. These are the main channel, main channel border, sandbar, pool, chute, backwater, and marsh. Physical features in the variety of habitats range from high flows and depths in the main channel to the near lentic conditions found in backwaters and marshes. The various habitats intergrade and provide an ever-changing set of riverine features.

The changes in land use that have occurred along the affected reach between 1944 and 1977 have been documented through the use of aerial photographs. However, only changes that have occurred since 1956 will be discussed because Gavins Point Dam, which controls the flows in this reach, was closed in 1955. The study area included the Missouri River and approximately 0.5 miles of adjoining land on both sides of the river channel (total area = 39,680 acres). Due to their transient nature, low sandbars were included in the river channel acreage. Five habitat types were identified and measured: cottonwood-dogwood, willow-cottonwood, sand dunes, elm-oak, and agricultural lands.

The study corridor, in 1956, consisted of 25,460 acres of land and 14,220 acres of water or river channel. By 1977, erosion of stream banks had expanded the river channel by 324 acres so the land:river channel ratio was 25,136 acres of land to 14,544 acres of river channel. Erosion rates were highest on agricultural land.

Agricultural acreage has increased from 7,844 acres in 1956 to 12,849 acres in 1977. This gain has resulted from encroachment on the various nonagricultural habitats, particularly the cottonwood-dogwood association. In 1956, there were 10,303 acres of cottonwood-dogwood; but, by 1977, this had been reduced to 6,012 acres. Approximately 2,660 acres of sand dune habitat were also lost between 1956 and 1977. While erosion caused some of the loss, the majority of the loss resulted from the clearing of land for agricultural purposes.

The 58 miles of river in the Recreational River and the 36.3 miles of open river below Fort Randall Dam are the only portions of the Missouri River, in South Dakota and Nebraska, that remain in a relatively natural state. The remainder of the river, from the North Dakota border downstream to the river's mouth near St. Louis (1,137 miles), has either been impounded or channelized. These developments, in addition to altering the river, either inundated the various habitats on the floodplain or facilitated their conversion to other uses; in particular, agriculture. Through the Recreational River designation, an attempt is being made to preserve a remnant of what was a corridor of river and woodland habitat spanning the prairie of Nebraska and the Dakotas.

Legislative Background

Initial authorization of the Missouri River Demonstration and Evaluation project was granted under Section 32 of the Water Resources Development Act of 1974. This Act directed the Chief of Engineers to:

a. Evaluate the extent of stream bank erosion nationwide.

b. Develop new methods and techniques for bank protection and research on soil stability and identify the causes of bank erosion.

c. Prepare a report to Congress on the results of such studies and recommend means for the prevention and correction of stream bank erosion.

d. Construct demonstration projects, including bank protection works, at a minimum at multiple sites on:

(1) The Ohio River;

(2) That reach of the Missouri River between Fort Randall Dam, South Dakota, and Sioux City, Iowa;

(3) That reach of the Missouri River in North Dakota at or below the Garrison Dam; and,

(4) The delta and hill areas of the Yazoo River Basin generally in accordance with the recommendations of the Chief in his report dated September 23, 1972.

Section 155 of P.L. 94-587 amended the original Act by adding two additional reaches for construction of demonstration projects. These are:

a. The delta of the Eel River in California; and,

b. The Lower Yellowstone River from Intake, Montana, to the mouth of that river.

This section also increased the funding level from $25 million to $50 million.

Section 161 of P.L. 94-587 further amended the original Act by listing 21 specific sites below Garrison Dam where demonstration sites may be constructed. It required an interim report to Congress by September 30, 1978, and extended the date of the final report to Congress from June 30, 1978, to December 31, 1981.

Although the original Act has been amended, the original purposes of the Act have not been changed.

As stated in the Act and as substantiated by its legislative history, the Section 32 Program is meant to be a feasibility-level study to determine the extent and causes of erosion and development of new methods and techniques for bank protection with authorization to construct a limited number of erosion control structures for evaluation and demonstration. The U.S. Army Corps of Engineers seems to be implementing the Section 32 Program as an authorized construction project with continuing authority. We are concerned that this project, that is National in scope, will continue to be provided additional funds and that it will continue to be treated as an authorized construction project without provisions for adequate enhancement or loss prevention/compensation measures.

We firmly believe the Section 32 Program should be viewed as a feasibility-level study and that it should be carried out, as such, under the Water Resources Council's Principles and Standards.

Description of the Project

For purposes of this report, the "project area" is considered to be the free-flowing reaches of the Missouri River from Fort Randall Dam to Lewis and Clark Lake and Gavins Point Dam to Sioux City, Iowa.

On the Missouri River below Gavins Point Dam, demonstration projects were initially planned for six site· three on each side of the river. Each project would include 1 to 3 miles of eroding bank line. They were to include a variety of structures of less traditional design and materials. The six projects were to be constructed, and then the environmental impacts were to be evaluated.

In August 1977, Congress appropriated $2 million for bank stabilization demonstration structures at three more sites between Fort Randall Dam and Sioux City, Iowa - Sunshine Bottom below Fort Randall Dam and Goat Island and Ionia Bend below Gavins Point Dam.

In 1979, another two demonstration sites, Cedar County Park and Elk Point, were added within the reach below Gavins Point Dam. In 1980, the White Swan area was stabilized within the Fort Randall reach.

Generally, five types of structures are being utilized within the Fort Randall to Sioux City reach of the Missouri River. They include windrow revetments, windrow refusals, reinforced revetments, composite revetments, and hard points.

Windrow revetment consists of stone fill placed in a trench or notch immediately adjacent to the bank. The stone is covered with earth fill, graded, and seeded.

Windrow refusals are similar to windrow revetment in construction, except that each structure is short (30 to 75 feet) and perpendicular to the bank.

Reinforced revetment consists primarily of a low elevation stone-fill toe placed riverward of the eroding bank. Narrow stone-fill "tiebacks" are placed at designed intervals along the toe. Each "tieback" extends from the toe landward to or into the existing bank. Grooved concrete slabs were used in some revetments and covered with gravel and soil.

Composite revetment consists primarily of a low elevation stone-fill toe placed riverward of a bank with a thin cover layer of gravel placed over the stone.

Hard points consist of a stone-fill root and a stone-fill spur, which respectively extend landward and riverward from the bank a distance of 30 to 50 feet. The crown of each hard point slopes down from the bank to normal water surface and is covered with gravel or topsoil.

Environmental Setting Without the Project

Fishery Resources

The relatively unaltered reaches of the Missouri River support a fish community of a minimum of 50 species. Schmulbach et. al. (1975) listed 113 species that could occur in the Missouri River. Most recent surveys of the fish fauna have reported 40 to 50 species. Table 1 lists the fish species found by Kallemeyn and Novotny (1977) in the unchannelized reach. Of these species, sauger, carp, channel catfish, freshwater drum, and white bass are the most abundant fish in the fisherman's creel. Sport fish harvest rates from the Missouri River were comparable with those from smaller warmwater rivers in the upper Midwest (Groen and Schmulbach 1978). Catch and harvest rates are greater in the unchannelized river than in the channelized river.

The continued existence of the fish community and the fishery of this Missouri River reach is dependent on the maintenance of the variety of habitats that exist in the unaltered reaches. Kallemeyn and Novotny (1977) concluded that even though some fish species exhibited preferences for particular habitats, most required several habitats to successfully complete their life span. Thus, disruption of the system of habitats in a river reach will result in widespread changes in the fish community. Such changes are evident in the channelized Missouri River where the total aquatic surface area per linear mile has been reduced to one-third of that on an equal distance in the unchannelized river (Morris et. al. 1968). Chutes, sloughs, and other associated backwaters which are important spawning and nursery areas for fish indigenous to the river have been virtually eliminated. The loss of these areas has had an adverse effect on fish recruitment within the river. These factors contribute to the reduction in the fish carrying capacity of the channelized Missouri River.

Species that evolved under riverine conditions, such as pallid sturgeon (which may never have been adundant), paddlefish, and certain chubs and minnows, are particularly susceptible to habitat alteration. Where the Missouri River has been impounded or channelized, these species have either disappeared or been reduced to extremely low numbers. These reductions have caused the South Dakota Department of Game, Fish and Parks to place the pallid sturgeon, sturgeon chub (*Hybopsis gelida*), and sicklefin chub (*Hybopsis meeki*) on its list of threatened fish while the Nebraska Game and Parks Commission has designated the pallid sturgeon and lake sturgeon (*Acipenser fulvescens*) as threatened. Paddlefish have

Table 1. Fish species collected from stations in the Missouri River, April-October 1976.

COMMON NAME	SCIENTIFIC NAME[a/]
Pallid sturgeon	Scaphirhynchus albus (Forbes and Richardson)
Shovelnose sturgeon	Scaphirhynchus platorynchus (Rafinesque)
Paddlefish	Polyodon spathula (Walbaum)
Longnose gar	Lepisosteus osseus (Linnaeus)
Shortnose gar	Lepisosteus platostomus (Rafinesque)
American eel	Anguilla rostrata (Lesueur)
Skipjack herring	Alosa chrysochloris (Rafinesque)
Gizzard shad	Dorosoma cepedianum (Lesueur)
Goldeye	Hiodon alosoides (Rafinesque)
Northern pike	Esox lucius (Linnaeus)
Carp	Cyprinus carpio (Linnaeus)
Silvery minnow	Hybognathus nuchalis (Agassiz)
Silver chub	Hybopsis storeriana (Kirtland)
Emerald shiner	Notropis atherinoides (Rafinesque)
Bigmouth shiner	Notropis dorsalis (Agassiz)
Red shiner	Notropis lutrensis (Baird and Girard)
Sand shiner	Notropis stramineus (Cope)
River carpsucker	Carpiodes carpio (Rafinesque)
Quillback	Carpiodes cyprinus (Lesueur)
White sucker	Catostomus commersoni (Lacepede)
Blue sucker	Cycleptus elongatus (Lesueur)
Smallmouth buffalo	Ictiobus bubalus (Rafinesque)
Bigmouth buffalo	Ictiobus cyprinellus (Valenciennes)
Shorthead redhorse	Moxostoma marcolepidotum (Lesueur)
Black bullhead	Ictalurus melas (Rafinesque)
Channel catfish	Ictalurus punctatus (Rafinesque)
Flathead catfish	Pylodictis olivaris (Rafinesque)
Burbot	Lota lota (Linnaeus)
White bass	Morone chrysops (Rafinesque)
Green sunfish	Lepomis cyanellus (Rafinesque)
Orangespotted sunfish	Lepomis humilis (Girard)
Bluegill	Lepomis macrochirus (Rafinesque)
Largemouth bass	Micropterus salmoides (Lacepede)
White crappie	Poxomis annularis (Rafinesque)
Black crappie	Poxomis nigromaculatus (Lesueur)
Iowa darter	Etheostoma exile (Girard)
Johnny darter	Etheostoma nigrum (Rafinesque)
Yellow perch	Perca flavescens (Mitchill)
Sauger	Stizostedion canadense (Smith)
Walleye	Stizostedion vitreum vitreum (Mitchill)
Freshwater drum	Aplodinotus grunniens (Rafinesque)

a/Nomenclature follows the American Fisheries Society's Special Publication No. 6, "A List of Common and Scientific Names of Fishes from the United States and Canada," Third Ed. 1970, 150 pp.

not been classified as either threatened or endangered, even though they have virtually been eliminated in those river reaches where the whole reach has been converted to a reservoir. Thus, the Recreational River reach and the reach of river below Fort Randall Dam are considered essential to the continued maintenance of the populations of paddlefish, sturgeons, and other riverine species in the Missouri River.

Wildlife Resources

The various habitats that exist in and along the unaltered reaches support a large and diverse wildlife community. Clapp (1976), in his study of the wildlife habitats along the unchannelized Missouri River in South Dakota, presented lists of the mammals, birds, reptiles, and amphibians that may be expected to occur in the area.

The list of mammals includes 51 species, with small mammals such as mice, voles, bats, moles, rats, and ground squirrels comprising over 50 percent of the species. Furbearers in the area are beaver, muskrat, mink, red fox, raccoon, coyote, skunk, and oppossum. VandenBerge (1976) estimated that the beaver population in the Recreational River reach consisted of approximately 200 animals and was capable of supporting an annual harvest of 50-75 animals per year. The area also supports populations of Eastern cottontail and fox squirrel, both of which are classified by South Dakota and Nebraska as small game animals. White-tailed deer, a big game animal, is present in significant numbers; and occasionally mule deer are seen. The extensive breaks along the Nebraska side of the river, coupled with the interspersed brush, timber, and cultivated land on the floodplain, comprise good deer habitat. The South Dakota Department of Game, Fish and Parks estimates that there are approximately 15 deer per square mile along the river. The average density for good white-tailed deer habitat in South Dakota is 2.9.

The bird list for this area includes 269 species, of which 29 are classified as being permanent residents of southeastern South Dakota. An additional 96 species are summer residents. Another 25 species commonly winter in the area. Over 115 species regularly use the corridor on their spring migration and 110 during the fall migration.

The bald eagle, an endangered species, winters on the open river reaches below Gavins Point and Fort Randall Dams. Mid-winter (first or second week of January) counts of bald eagles along the Gavins Point reach during the past five years ranged from 16 to 36 with an average of 28 birds. The eagles usually arrive in November and remain until March or early April. They use the large cottonwoods along the river for roosting and as perches from which they watch for prey. In early winter, they feed primarily on fish. Later in the season, they eat waterfowl, upland game animals, and carrion.

The first National Wildlife Refuge created specifically for bald eagles is located two miles downstream from Fort Randall Dam, primarily on the timbered floodplain of the Missouri River. The eagles winter in stands of mature cottonwoods adjacent to the open water. The river, which is ice-free throughout the winter, provides an abundance of fish, such as goldeye, shad, and white bass, plus wintering ducks and geese (mostly mallard and Canada geese). In 1967, a peak of 283 eagles was observed, establishing the Fort Randall population of wintering eagles as the largest in the lower 48 States. More recent counts tend to be lower with numbers ranging from 100 or more in mild winters to 200+ in severe winters.

The Interior least tern is a summer resident in the area. This species is designated threatened in Nebraska and endangered within South Dakota. Breeding colonies use the clusters of specific nonvegetated sandbars that occur in the river between Vermillion, South Dakota, and Ponca State Park, Nebraska. This species is being studied for possible inclusion on the Federal endangered species list.

Although nongame birds comprise the largest percentage of the bird fauna in the river corridor, game birds receive most of the public attention. Pheasant, bobwhite quail, Hungarian partridge, woodcock, and mourning dove use the mosaic of forest, brush, and agricultural lands on the floodplain. The project area offers fair to good hunting for these species. Although turkeys live on both sides of the river, the largest numbers live in the wooded breaks on the Nebraska side of the river. In this area, South Dakota and Nebraska have a spring hunting season for male turkeys. Nebraska also has a fall season for male and female turkeys.

The project reaches of the Missouri River are particularly important to many species of migratory waterfowl and shorebirds because of the project's location within the Central Flyway. Thousands of ducks and geese use the river as a staging area as they migrate to their northern nesting grounds. In addition, mallard, gadwall, blue-winged teal, shoveler, and wood duck nest along the river. The open river reaches provide quality snipe, rail, and waterfowl hunting. The principal ducks harvested are mallard, pintail, green-winged and blue-winged teal, scaup, gadwall, and baldpate, while hunters also take blue, snow, and Canada geese. Sites for hunting blinds are in great demand along both river reaches, with the number of blinds averaging five per mile.

The amphibians and reptiles that may occur in the project area include one salamander species, nine species of frogs and toads, five turtle species, two lizard species, and twelve species of snakes. The South Dakota Department of Game, Fish and Parks has placed several species that live in the area on its list of threatened species. They are the false map turtle, Eastern hognose snake, and lined snake.

Environmental Impacts With the Project

Fishery Resources - Aquatic Impacts

Essentially 5 types of bank stabilization structures installed mainly for agricultural land and cabin development protection - windrow revetments, composite revetments, hard points, windrow refusals, and reinforced revetments - were studied to determine their impact on the aquatic environment. In general, our assessment is qualitative rather than quantitative for projects completed within the Fort Randall to Sioux City reach. A more thorough quantitative assessment of aquatic impacts may be forthcoming via a U.S. Army Corps of Engineers' contract with the Fish and Wildlife Research Laboratory at LaCrosse, Wisconsin. Structures placed in the Missouri River under the Section 32 authority within North Dakota are being studied to determine their impact on fish habitat. Our qualitative assessment of aquatic impacts is as follows:

Within the Gavins Point river reach, nine projects have been completed or are nearing completion. Below Fort Randall, one project has been completed and another is under construction. Approximately 64,400 linear feet of natural bank line have been armored with stone. Within project areas, gaps exist between structures; therefore, the overall project area has a direct effect on 27.45 miles of bank line (Table 2).

Table 2. Project areas.

Gavins Point Reach of River

Project Name	Structural Type	Bank Line Effected	Project Length
Brooky Bottom Road	Composite Revetment	2,200'	
	Windrow Revetment	800'	
	Hard Points	11	3.44 mi.
Cedar County Park	Composite Revetment	2,320'	
	Windrow Revetment	800'	
	Reinforced Revetment	2,560'	
	Hard Points	7	1.89 mi.
Elk Point	Composite Revetment	4,880'	
	Windrow Revetment	3,400'	
	Reinforced Revetment	2,200'	
	Hard Points	11	3.4 mi.
Goat Island	Composite Revetment	3,200'	
	Windrow Revetment	1,800'	
	Reinforced Revetment	4,480'	
	Hard Points	5	2.87 mi.

Table 2 cont.

Gavins Point Reach cont.

Project Name	Structural Type	Bank Line Effected	Project Length
Ionia Bend	Composite Revetment	3,560'	
	Windrow Revetment	3,320'	
	Hard Points	12	3.37 mi.
Mulberry Bend	Composite Revetment	1,600'	
	Stone-fill Refusal	1,200'	
	Jetty	600'	1.68 mi.
Ryan Bend	Composite Revetment	1,680'	
	Windrow Revetment	2,240'	
	Reinforced Revetment	1,280	1.59 mi.
Vermillion Boat Club	Composite Revetment	4,800'	
	Hard Points	10	4.39 mi.
Vermillion River Chute	Composite Revetment	5,600'	
	Windrow Revetment	3,800'	
	Reinforced Revetment	1,280'	
	Hard Points	7	3.18 mi.
	Total Bank Line Armored	59,600 feet	25.81 miles

Fort Randall Reach of River

Sunshine Bottom	Composite Revetment	1,600'	
	Reinforced Revetment	3,200'	
	Hard Points	8	1.64 mi.

Installation of the bank stabilization materials, primarily stone or rock of varying sizes and composition, within natural habitat areas resulted in the removal of plants that grow on the bank and shade the main channel border; i.e., riparian vegetation. Within revetment areas, access for heavy equipment was provided by constructing haul roads adjacent and parallel to the bank. Haul roads are generally 20 to 40 feet wide. In areas where hard points were constructed, the access is generally perpendicular to the bank. Removal of a small number of trees (primarily cottonwood, dogwood, and red cedar) generally resulted in reduced shade within the main channel border area. This reduction in shade is not expected to cause increased water temperatures within the main channel border area, as the water is well mixed and the temperature is more or less homogeneous throughout (Kallemeyn and Novotny 1977).

During project construction, bank stabilization activities, such as building up the toe of the slope with rock, pulling back the top of the bank, and replacing topsoil, cause a temporary increase in suspended solids load and sedimentation downstream. Long-term effects of all structural types are anticipated to include a decrease in suspended solids and sedimentation problems (Barton 1977, Yorke 1978). Within the stabilized area, there is a decrease in erosion, particularly where banks are armored by revetment. Gaps between the structures supply a limited amount of sediment for a short time but are expected to stabilize under the influence of adjacent structures.

In areas where water depth, velocity, etc. were sufficient, construction was accomplished from a barge. Generally, when working from a barge, the stabilization structures were constructed with a minimum loss of trees and disturbance to the aquatic environment.

Hard points, structures that project 30 to 50 feet into the river channel, produce a permanent scour hole at the tip of the structure two to six feet deeper than the riverbed. The scour hole and structure provide habitat not previously available for fishes. The area between hard points is anticipated to reach equilibrium in a few years, carving out a concave bank between structures. Local cabin owners and visiting recreationists are using the hard points as boat landings and favored fishing areas.

At Mulberry Bend, a rock-fill jetty was constructed that projects 200 to 300 feet into the river channel. The structure has produced a permanent scour hole at the downstream base of the structure six to ten feet deeper than the riverbed. The area between the downstream end of the jetty and the bank line is becoming a slow or slack-water area and is collecting dead trees and debris. The scour hole, slow water, and accumulated debris provide habitat not previously available for fishes. The jetty surface, which protrudes above the water surface, is a favored fishing access for local sportsmen.

The visual or aesthetic effect of structural types is varied. Windrow revetments have the greatest visual impact. As rock washes into the river, the entire surface of the exposed bank is covered with rock. The angle of repose is such that fishermen and recreationists will find it difficult to negotiate such a steep bank. Within some areas, notably the Vermillion River Chute area, windrow revetments are composed of fieldstone. Although the main body of the structure is fieldstone, the tiebacks or windrow refusals at the upper and lower ends of the structures were constructed using pink quartzite. The visual effect is unnatural and should be modified as project funds are made available for maintenance or enhancement of structural types.

Hard points, although obtrusive, cover the least amount of bank line, leaving a greater proportion of natural bank exposed within a protected reach. This structural type is, therefore, preferable from an aesthetic viewpoint.

Composite and reinforced revetments, when covered with gravel and soil and revegetated, appear fairly natural except where fluctuation of the water level exposes the rock. If willows become established, they may overhang and camouflage the exposed rock.

Generally, the structures detract from the natural setting. The contrast of vertical cutbanks between structures and the sloped, vegetated structural surface with exposed pink quartzite, fieldstone, limestone, or shale is stark and unnatural. The loss of natural setting and the associated aesthetic appeal of the area cannot be mitigated.

Open river aquatic and semiaquatic habitat on the Missouri River has become scarce since the construction of the main-stem dams and the navigation channel downstream from Sioux City (U.S. Fish and Wildlife Service 1980). Although the ongoing erosion process reduces terrestrial wildlife habitat, it creates new shallow-water aquatic habitat. Stabilization of the riverbanks is preventing and/or greatly reducing the erosion process. With stabilization of the banks, the river will no longer be free to migrate and produce new river surface area or new side channels. As a result, the potential for new aquatic habitat available for aquatic organisms will be lost. Within the Gavins Point reach of the river, a gross future loss projection of 3.72 upland acres per river mile per year is anticipated (Corps of Engineers 1980). Within the Fort Randall reach, a gross future erosion loss projection of .83 acres per river mile per year is anticipated (Final EIS, Missouri River South Dakota, Nebraska, North Dakota, Montana; Streambank Erosion Control, Corps of Engineers 1978). Approximately 85 acres of new aquatic habitat will be prevented from forming each year over the life of the present projects. This loss of potential aquatic habitat may be significant to the long-term productivity of the river when considered in conjunction with other bank stabilization segments being considered for these river reaches. Long-term monitoring will be necessary to determine changes and establish causes of changes within the river reaches.

<u>Wildlife Resources - Terrestrial Impacts</u>

This Service has evaluated wildlife habitat within the area of the projects. Our evaluation is based primarily on aerial mosaics of the project area on a scale of 1 inch:2,000 feet provided in 1977 and aerial photos on a scale of 1 inch = 1,000 feet provided by the Corps of Engineers in 1979. Nondeveloped land (natural habitat) within the project

area was delineated and classified according to terrestrial cover types. The terrestrial cover types for the Gavins Point and Fort Randall reaches of the Missouri River contain five major categories: (1) sand dune, (2) cattail marsh, (3) cottonwood-willow, (4) cottonwood-dogwood, and (5) elm-oak (Clapp 1976).

Clapp (1976) identified, delineated, and measured all habitats within approximately one kilometer of the free-flowing Missouri River between Fort Randall Dam and Sioux City, Iowa. He also quantitatively described the understory and overstory of naturally vegetated habitats and, subsequently, assigned a wildlife habitat value to each of the natural habitats. The values derived by Clapp (1976) were used in our evaluation to determine the relative wildlife habitat value of natural habitat within the project sites. Procedures used to rate the habitat are outlined in the Habitat Evaluation Procedures Manual (U.S. Fish and Wildlife Service 1976).

The value of natural habitat within the project area was determined by multiplying the acres of the habitat type by habitat values. The result was an index of the habitat value. The habitat values are shown in the right hand column of Table 3. We used a dot grid measurement for all area determinations. Nondeveloped lands (natural habitat) or lands of greatest value to wildlife comprise 23 percent of the area directly behind the protected bank line (Table 3).

Table 3. Habitat types within one kilometer of stabilization structures (1977).

	Agricultural Land	Wildlife Habitat	Habitat Units
Gavins Point Reach			
Brooky Bottom Road	331 (80%)	81 (20%)	596
Cedar County Park	652 (89%)	77 (11%)	608
Elk Point	545 (91%)	55 (.09%)	434
Goat Island	334 (76%)	107 (24%)	845
Ionia Bend	380 (84%)	74 (16%)	582
Mulberry Bend	119 (82%)	27 (18%)	178
Ryan Bend	73 (59%)	50 (41%)	399
Vermillion Boat Club	274 (52%)	248 (48%)	196
Vermillion River Chute	293 (78%)	81 (22%)	639
	3,001 (79%)	800 (21%)	4,477
Fort Randall Reach			
Sunshine Bottom	375 (64%)	207 (36%)	1,635
Totals	3,376 (77%)	1,007 (23%)	6,112

Impacts on terrestrial habitat varied among the sites depending on the existing land use within the immediate project area and the construction techniques employed by the contractors. Generally, within agricultural lands or near-bank areas occupied by cabin developments, loss of terrestrial habitat within the project areas has been minimal as a result of project construction. The greatest temporary loss of terrestrial habitat occurred in understory areas where construction of revetments resulted in the clearing of most low growing near-bank vegetation. In many instances, contractors attempted to and were successful in preserving large cottonwoods in close proximity to eroding bank lines. These trees are important to wintering bald eagles which will use them as perches.

Within cabin development areas, notably the Vermillion River Chute, Brooky Bottom Road, and Vermillion Boat Club areas, local landowners and casual visitors are interfering with natural succession within the project sites by using the project access roads and the installed structures for their personal use. Vehicle and foot traffic are retarding revegetation; and, in some instances, mowing and planting of lawns will preclude the appearance of a natural bank line.

Where stabilization structures were placed within natural habitats, some habitat has been lost as a result of project construction. Most of the loss occurred as a result of clearing cottonwood-dogwood habitat for haul roads and near-bank access for dragline equipment. The greatest loss occurred in natural habitats where construction of composite and reinforced revetments resulted in the clearing of most near-bank vegetation along the entire length of the project site.

Significant habitat losses were recorded at 4 of the 10 bank stabilization sites. At Sunshine Bottom, approximately 20 acres of cottonwood-dogwood habitat were cleared by an over-enthusiastic contractor. Below Gavins Point Dam, at Elk Point, Cedar County Park, and Ryan Bend, an additional 22 acres in excess to needs were cleared. The cumulative loss was approximately 321 habitat units. With judicious use of equipment and materials, any loss could have been avoided. The contractors at the 4 sites did not attempt to preserve large cottonwoods in close proximity to the eroding riverbank and generally removed all vegetation within 40 to 50 feet of the riverbank.

Beneficial Impacts

Fishery Resources

Placing rock of various sizes and composition supplies a previously unavailable substrate within the Gavins Point reach. The variable substrate may be beneficial in terms of macroinvertebrate production, spawning bed materials, and added habitat diversity.

Scour holes at the tip of hard points and the jetty at Mulberry point may provide additional deep water habitat at various flow conditions.

Publicly owned or controlled stabilization structures also provide added access for stream bank fishermen, except in windrow revetment areas where steep, unstable banks restrict access and are unsafe.

Wildlife Resources

Stabilization structures, if revegetated, may provide escape cover and feeding sites for species adopted to early successional stages. As succession progresses, species that are narrowly adapted to certain successional stages will benefit for the period of time that the seres are present.

Adverse Impacts that Cannot be Avoided

Fishery Resources - Aquatic Habitat

With project construction, the opportunity for the river to migrate and produce new river surface area and side channels is reduced. Each year that the project is in place, 85 acres of new aquatic habitat will be prevented from forming. This loss of potential aquatic habitat may be significant to the long-term productivity of the river, particularly if additional bank stabilization features are constructed within the Gavins Point and Fort Randall reaches.

The loss of the aesthetic experience of boating and fishing in a natural setting cannot be mitigated. Over 25 miles of bank line are now artificially armored within the Gavins Point reach. As more man-made structures are added, the opportunity for an aesthetically pleasing experience is diminished.

Wildlife Resources - Terrestrial Habitat

Terrestrial habitat has been lost as a result of project construction. Within the project areas, approximately 41 acres of dogwood-cottonwood habitat were cleared for haul road and near-bank access for dragline equipment. The greatest loss occurred in natural habitat areas where construction of composite and reinforced revetments resulted in the clearing of most near-bank vegetation. The contractors at 4 of the 10 sites did not attempt to preserve large cottonwoods in close proximity to the eroding riverbank.

Hard point construction should have resulted in the least amount of clearing of all structural types. However, the width of openings through the timbered bank line was excessive in some instances; and no attempt has been made to replant cottonwoods or other woody vegetation removed for access and bank line construction.

As a secondary or indirect impact, bank stabilization may encourage conversion of woodland to agricultural land. Since project construction, approximately 32 acres (253 habitat units) of cottonwood-dogwood habitat have been cleared in the Ryan Bend project area between the base line established by Clapp (1976) and the stabilization structures. An additional 51 acres (403 habitat units) have been cleared outside the established base line but still within the Missouri National Recreational River corridor boundary (Corps of Engineers 1980). It appears that the stabilization of the stream bank encouraged woodland clearing. However, other factors, such as those established in Jack Mielke's Master Thesis (1977), may have influenced decisions to clear the land. Establishing the principal cause of the clearing, i.e., agribusiness trends or federally financed bank stabilization, may be difficult to determine. Regardless, the direct or indirect loss of floodplain forest and the consequent loss of wildlife populations have apparently been influenced by federal involvement in this area.

Adverse Impacts that can be Mitigated

Fishery Resources - Aquatic Habitat

Structures placed within the Fort Randall to Sioux City reach are placed on existing high banks and do not constrict the river. However, their intended purpose is to restrict the river's movement within high bank limits, thus preventing an increase in aquatic habitat that could improve the long-term productivity of the river. Measures to maintain and assure the long-term productivity of the river should be incorporated in the project.

Wildlife Resources - Terrestrial Habitat

The major adverse impact on wildlife is the loss of trees and brush. Within the Fort Randall to Sioux City reach, timber has been cleared within specified project areas. The high-bank woodlands dominated by cottonwood trees are outstanding scenic features and have high value as wildlife habitat. Woodland values lost due to project construction should be replaced.

With most projects, wildlife habitat loss can be mitigated by initiating intensive wildlife management practices on mitigation lands to increase their carrying capacity to support more wildlife. Implementation of such management measures would replace the wildlife losses.

Project Modifications (Mitigative Measures)

Introduction

On November 10, 1978, President Carter signed Public Law 95-625 designating the reach of the Missouri River from Gavins Point Dam to Ponca State Park as a Recreational River under the Wild and Scenic Rivers Act. The legislation authorizing designation also includes provisions for the installation of bank erosion control measures that will be compatible with Recreational River concepts and maintain fish, wildlife, and associated environmental values. These actions are the result of coordination among and the participation of a wide range of interests, including the Corps of Engineers, the Heritage Conservation and Recreation Service, the Fish and Wildlife Service, State and local agencies, and private organizations and individuals. Implementation of fish and wildlife management plans can assure that environmental as well as bank erosion control concerns can be addressed at each project site, including those projects constructed under Section 32.

Fishery Resources

Most of the structures within the Gavins Point reach have been installed with due regard for aquatic environmental values. They do not reduce channel widths, nor eliminate oxbows or channel chutes. It remains to be seen whether they will induce erosion at new locations that will then need to be armored with additional structures.

Without data or long-term trends, the aquatic habitat conditions for the unchannelized reaches of the Missouri River cannot be predicted at this time. If the riverbanks are armored and bed degradation is accelerated or continues at its present rate, water levels of off-river aquatic areas will be lowered, thereby reducing water surface and marsh areas. As additional stabilization projects are built, river widening in some areas will be reduced, affecting the long-term productivity of the river. Any program to stabilize the riverbank should also consider water control techniques and methods to prevent dewatering of shallow water areas adjacent to the river.

Dredging or excavation could be used to restore former open-water areas. In addition to the physical restoration of habitat, these activities could improve water circulation and dissolved oxygen levels of existing water areas suffering from eutrophication. Improved circulation will provide open, slow-moving waters during winter months and may decrease winterkill in shallow backwater areas. Any such action must be examined in detail, on a case-by-case basis, as the potential for other adverse impacts also exists.

The position of stabilization structures relative to chutes, sloughs, and backwater areas could also benefit aquatic resources. Evidence suggests that proper chute closure will increase the longevity of the chute by retarding the natural sedimentation process. In some cases, the life of a chute channel may be increased if the upper end is closed off by a stabilization structure.

The chute channel could form a backwater area in which rates of sedimentation may be minimal. These potential alterations and modifications are offered to indicate techniques that might be employed to restore aquatic habitat. Final plans for any project modification will require a case-by-case on-site inspection by a team representing the State fish and wildlife agency, the Fish and Wildlife Service, and the Corps of Engineers. Work can be accomplished under existing authority; i.e., Section 32; Executive Order 11990, Protection of Wetlands; Environmental Water Quality Operational Studies; or legislation authorizing the Missouri National Recreational River.

Wildlife Resources - Direct Habitat Loss

Results of field surveys and aerial photo interpretation indicate that a total of 41 acres (321 habitat units) were lost as a result of clearing wildlife habitat within project areas. This loss is not considered large, nor is it an irretrievable commitment of resources, so long as the cleared areas are not dedicated to agricultural production or other incompatible land uses.

If clearing of timber and brush within the project right-of-way had been limited to the minimum amount necessary at the Sunshine Bottom and Elk Point areas, 92 percent (37 acres) of the loss attributable to the present project would have been avoided.

Cleared areas within project sites have been reduced to a grass forb sere or first stage of succession. Populations of species of wildlife which were dependent on the cottonwood-dogwood sere, which takes approximately 15 years to develop and lasts for approximately 40 years (Johnson 1949), have been displaced or lost. Full recovery of the habitat in about 15 years will occur with planting of seedlings. These areas would then continue to provide good cottonwood-dogwood habitat for at least 40 years, if protected from further development.

Regeneration at specified sites is varied. Within some areas, grazing is eliminating regeneration (Goat Island); and, in others, recreational activities are destroying vegetation and compacting soils (Cedar County Park). Other stabilization sites, free of continuous human use and cattle grazing, are developing woody vegetation in addition to the grasses and forbes (Brooky Bottom Road, Mulberry Bend).

Recreationist and landowner activities, such as clearing, mowing, trampling, and cattle grazing, are the major factors contributing to the failure of riparian communities to propagate the surface of stabilization structures. An expedient procedure to rejuvenate riparian vegetation and give a more natural appearance to the project areas is to discourage cattle grazing by fencing the areas and providing watering access between structures. Within built-up areas, we encourage planting of the near-bank area with native species of trees and shrubs and discourage clearing, mowing, and vehicular use of project-created access roads. It may be necessary to fence the access roads near the bank line and provide foot access only to structural areas.

Within the Sunshine Bottom area below Fort Randall Dam, approximately 20 acres (158 habitat units) of cottonwood-dogwood habitat were lost as a result of project construction. Most of the loss was within the near-bank areas where natural vegetation was removed from the bank line.

In the Biological Assessment, pursuant to Section 7(c) of the Endangered Species Act, for the Section 32 Streambank Erosion Control Evaluation Demonstration Program, U.S. Army Corps of Engineers; Omaha, Nebraska, 1979, protective and remedial measures A through G for the protection of the bald eagle and its habitat were to be employed within the project area. Protective measures A and B were not used. In addition, no attempt has been made to comply with "C"; i.e., "All areas disturbed during construction will be revegetated. Haul roads in woodland areas will be obliterated and revegetated with cottonwoods and indigenous grasses." In order to fully comply with the preservation assurance, it will be necessary to replant cottonwoods.

Concern for the retention of natural and aesthetic values within the Fort Randall reach of the Missouri River was pointed out in the Recreational Work Group Technical Papers in 1967 and later in the Missouri River Basin Comprehensive Framework Study of 1971. The Fort Randall reach is also included in the Nationwide River's Inventory conducted by the western regions of the Heritage Conservation and Recreation Service (HCRS). This study identifies the Fort Randall reach as one of the few remaining free-flowing streams best suited for conservation. The high-bank woodlands dominated by cottonwood trees are outstanding scenic features and have high value as wildlife habitat. We believe the most effective and efficient protection for the woodland area would be for the Corps of Engineers to obtain easements within the Sunshine Bottom area pursuant to the Endangered Species Act mandates as soon as possible, then replant cottonwood trees destroyed by the contractor, and prevent conversion of woodlands to other uses. In addition, comprehensive management alternatives should be developed for this reach of river which fully integrate environmental, recreational, aesthetic, and stream bank erosion control alternatives. These alternatives can include provisions for the installation of bank erosion control measures and

measures that will maintain fish, wildlife, and associated environmental values. Such action would be consistent with Executive Order 11988, Flood Plain Management, which directs agencies to preserve the natural and beneficial uses of the floodway. Actions similar to those taken in the Gavins Point reach of river, that lead to designation as a Scenic or Recreational River under the Wild and Scenic Rivers Act, should also be fully considered.

Wildlife Resources - Indirect Habitat Loss (Secondary Impacts)

As a secondary impact, bank stabilization encouraged conversion of woodland to cropland. Since project construction, approximately 32 acres (253 habitat units) of cottonwood-dogwood habitat have been cleared in the area between the base line established by Clapp (1976) and the stabilization structures at Ryan Bend. An additional 51 acres (403 habitat units) have been cleared outside the established base line but still within the Missouri National Recreational River corridor boundary (Corps of Engineers 1980). It appears that the presence of the existing stabilized stream bank encouraged woodland clearing.

Since the area was cleared after November 1978, measures through the Missouri Recreational River long-range operation and maintenance program should be incorporated into the present project to obtain easements and agreements to reestablish vegetation within the cleared area. If such an agreement cannot be negotiated, consideration should be given to implementation of the condemnation authority established by Section 707 of Public Law 95-625.

Within the Gavins Point reach, the Recreational River authority requires Federal assumption of operation and maintenance of all existing bank stabilization projects providing that landowners make available those interests in lands necessary to achieve Recreational River objectives. The high-bank woodlands dominated by cottonwood trees are outstanding scenic features and have high value as wildlife habitat. We believe the most effective and efficient protection would be for the Corps of Engineers to obtain scenic easements within all project areas pursuant to the Recreational River authorization as soon as possible in order to prevent conversion of woodlands to other uses.

Although no increase in conversion rates can be attributed to the Sunshine Bottom project (in place only two years), protective measures should be employed to reduce potential tree removal by landowners.

Mechanisms available to control tree removal within the Fort Randall reach include the provisions of the Endangered Species Act and mitigative measures recommended pursuant to the Fish and Wildlife Coordination Act.

We have not thoroughly investigated opportunities for enhancement of fish, wildlife, or environmental values. Enhancement of endangered species habitat should receive priority consideration in future studies of the Missouri Recreational River. Enhancement of State listed species habitat (such as enhancement of sandbars utilized by least terns through deposition of sand or mechanical clearing of vegetation from sandbars) is but one example of opportunities that should be explored.

Summary

It is our considered opinion that the potential long-term losses of resources and productivity that will result from the National Section 32 Program outweigh its relatively short-term gains. To date, projects appear to provide protection from erosion but markedly alter the character of the two remaining relatively natural reaches of the Missouri River in South Dakota and Nebraska. Riverine habitats, such as those in the project area, have become, and are becoming, increasingly scarce in South Dakota and Nebraska and in many other parts of the Nation. As a result, those remaining have a high value and are becoming increasingly valuable.

Actions to solve bank erosion problems have the potential for preserving these habitats. However, they also have the potential for destroying or significantly damaging them if carried to extremes or carried out without sensitivity to natural values. Measures must be taken to prevent or reduce losses or preserve and restore these environments.

High-value riparian habitats can be protected, in some instances, by installing appropriate erosion control devices in specified locations. However, this action can precipitate land clearing when carried out to protect private land. Therefore, it must be followed up by purchase in fee or easement to protect the public values of these habitats.

In other instances, no action or acquisition of adjacent eroding lands may be the least-cost alternative to solving a bank erosion problem while at the same time maintaining the existing riverine ecosystem. Such action would not only maintain the diversity of terrestrial habitat adjacent to the river but would preserve aquatic habitats as well.

We recognize that some structures will be necessary. However, wherever structures are built, they should be of the "soft" type (no more than necessary to check erosion) and be installed with due regard to potentials for changing instream hydraulics which could affect aquatic environmental values. They should not reduce channel widths nor eliminate oxbows, nor should they induce erosion at new locations that will then be considered for additional structures.

Proper maintenance that will allow the reestablishment of native vegetation on structures will not only provide wildlife and fishery habitat but will meet aesthetic criteria as well. These potentials can be developed by incorporating the fish and wildlife environmental concerns into the early study and planning process.

Recommendations

We recommend that before proceeding with extensive bank stabilization within the remaining free-flowing reaches of the Missouri River:

(1) That each site selected for demonstration purposes be treated individually and that an adequate mitigation plan be developed for each site, as is done with other projects, pursuant to the Fish and Wildlife Coordination Act, 16 U.S.C. 661 et. seq.

(2) That such mitigation plans include nonstructural as well as structural measures required to protect aquatic habitats and terrestrial wildlife habitats associated with the river.

(3) That the U.S. Army Corps of Engineers seek specific authorization to acquire land or interest in lands deemed necessary to protect, enhance, and preserve fish, wildlife, and other values within each project area.

We also recommend:

(1) Further investigations of aquatic impacts be undertaken, including an examination of benthic communities populating the various rock materials utilized in construction, potential spawning over the materials, and long-term monitoring to determine if energy that is no longer dissipated in eroding the newly riprapped bank will be transferred to unprotected banks downstream or to the riverbed. Increased bed degradation may lower the river's water surface, thereby dewatering wetlands and backwater areas contiguous to the river which are important to the production of river-inhabiting fish species.

(2) Further investigation of terrestrial impacts to include long-term monitoring to determine whether additional timber clearing is induced by the construction of stabilization features and to determine if energy that is no longer dissipated in eroding newly protected banks will be transferred to an unprotected reach elsewhere.

(3) Further investigation should also be made of the loss of future wildlife habitat via the accretion process; i.e., the prevention of habitat development through the building of the stabilization structures.

It is our view that the legislation authorizing addition of the Gavins Point to Ponca State Park reach of the Missouri River to the National Wild and Scenic Rivers System provides the Corps with sufficient authority to prevent or mitigate losses associated with construction at demonstration sites within this reach. Within the Fort Randall reach, our view is that the Endangered Species Act provides such authority, including authority to acquire land or interests in land, sufficient to preserve high-bank habitats. We firmly believe that a balanced program stabilizing high-bank areas, only where necessary, with due consideration to preserving environmental values at each project site should be followed.

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